UNHOLTZ-DICKIE CORPORATION

vibration generation systems and measurement instruments

OPERATING INSTRUCTION MANUAL
MODEL D22PMS, SN 1127-1132

OPERATING AND SERVICING INSTRUCTIONS

MODEL D22 SERIES

SIGNAL CONDITIONING AMPLIFIER

MODEL D22PM S

SERIAL NUMBERS 1127-1132

SUMMARY

CIRCUIT SCHEMATICS: B12362, B12522, C12496

F.S. TAPE OUTPUT: 10 V pk

L.P. FILTER 3 POLE ± 2 % AT 2 kHz

H.P. FILTER ____ POLE ± ____ % AT ____

SPECIAL FEATURES: S

UNHOLTZ-DICKIE CORPORATION

3000 WHITNEY AVENUE

HAMDEN, CONNECTICUT 06518

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1. GENERAL DESCRIPTION

The U-D Model D22 Series Signal Conditioning Amplifier is a low-noise, solid-state, data-acquisition instrument. It generally supersedes the D11 Series instrument, and the provision of modular construction, a vinyl-clad case, self-contained power supply, and rear-mounted connectors make it equally suitable for single-unit bench operation or multi-channel rack mounting. The design makes extensive use of integrated circuits and plug-in circuit cards.

The D22 Series has three primary divisions, each of which satisfies a wide application area. The "BASIC" D22PM is a charge amplifier which satisfies most general laboratory needs. The instrument accepts inputs from piezoelectric transducers to an internal charge converter or provides DC power to a remote two-wire preamplifier, and accepts the signal from the preamplifier. The remote preamplifier is either a Model 22CA-2 Charge Preamp or a Model 11PA-2 Voltage Preamp.

The "RED-HOT" D22PMH, is a high-performance charge amplifier with high-temperature (differential) amplifiers. High-temperature accelerometers exhibit a rapid decrease of shunt resistance above a critical temperature. Operation without blocking or excessive noise is possible with as little as 10 kilohms shunt resistance. Operation with a remote preamplifier is also provided.

The "MULTI" D22PMR can operate in a variety of input modes. Charge and voltage amplifier modes are provided for piezoelectric transducers. Another mode provides accurate constant-current excitation for a two-wire strain gage and AC amplification for the strain-gage output. Simple strain-gage sensitivity normalization is accomplished with the same controls that are used for the piezoelectric transducers. Remote preamplifiers are also accommodated.

All D22 instruments include the differential feature which allows separate ground systems for the amplifier input and output circuits. This allows the case of the input transducer to be grounded at the test site, without introducing amplified ground potentials at the signal output. This feature was pioneered in the Model D11 Series instruments.

The input signal is conditioned to provide higher level outputs required for monitoring and recording purposes. A variable-gain, range-switched output suitable for tape recording is standard on all models.

The following table summarizes the outstanding features and helps select such options as meters, log DC output, external range control, and autoranging.

FEATURE/OPTION	OPTION LETTER/ NUMBER	"BASIC" D22PM	"RED-HOT" D22PMH	"MULTI" D22PMR	COMMENTS
Internal/Remote Preamp	P	S	S	S	
Ground Loop Signal Rejection	D	S	S	S	
1-10, 10-100 Sens Ranges	-	S	S	S	
10 Turn Locking Sens Pot	-	S	S	S	U-D Dial-A-Gain
10 Turn Tape Gain ±10V F.S.	-	S	S	S*	*±1V F.S.
Fixed Plug-In LP Filter	-	S	N	S	3-Pole Butterworth
In/Out Switch LP Filter	-	N	S	N	6 & 10 Pole Also Avail
In/Out Switch HP Filter	-	N	S	N	6 & 10 Pole Also Avail
Test, F-Cal, V-Cal Modes	-	S	S	N	
Meter-Edge Reading ±2% F. S.	M	S	S	S	
Diff Accel (Hi-Temp) Input	H	N	S	N	Includes K
Single Ended Hi-Temp Input	K	O	S	O	
Strain Gage. Charge. Volt Input F-CAL Strain Gage Cal	R	N	N	S	
10 mV/g Servo Output	S	O	O	O	
100-110 mV-sec/in vel output	I	O	O	O	Requires S
1 V/in DA Disp Output	II	O	O	O	Requires S&I
Linear DC Output	F	O	O	O	
Log DC (1V/20dB) Output	L	O	O	O	Requires M
Manual Ranging 1-3-10 full-scale	-	S	S	S	
Remote Range Control 2 Wire TTL-4 Decade Ranges	E	O	O	O	
Automatic Range Selection 4 Decade Ranges	A	O	Z	Z	Includes E Requires M
High Current Line Driver ±100 mA	C	O	O	O	Current Booster For Tape Output
Independent Galvo Driver ±100 mA Adjustable full-scale out	G	O	N	N	Includes Separate 10T Potentiometer
Calibration Oscillator 100mV pk-100 Hz	O	O	O	O	
Tracking Filter	T	O	O	O	
Freq Resp ±5% 2Hz to 30kHz	-	S	S	S	
Extended Low Freq. ±5% 0.5Hz	-2	O	O	O	
Extra X 10 Gain	-3	O	O	N	.01 F.S. For 10-100 Sens
Full-Scale Relay Calibration	-4	O	O	O	
Large 2½" Scale Meter	-8	O	Z	Z	8.75 In Panel Height

S-STANDARD FEATURES O-OPTION AVAILABLE N-NOT AVAILABLE IN THIS SERIES Z-CONSULT FACTORY FOR AVAILABILITY

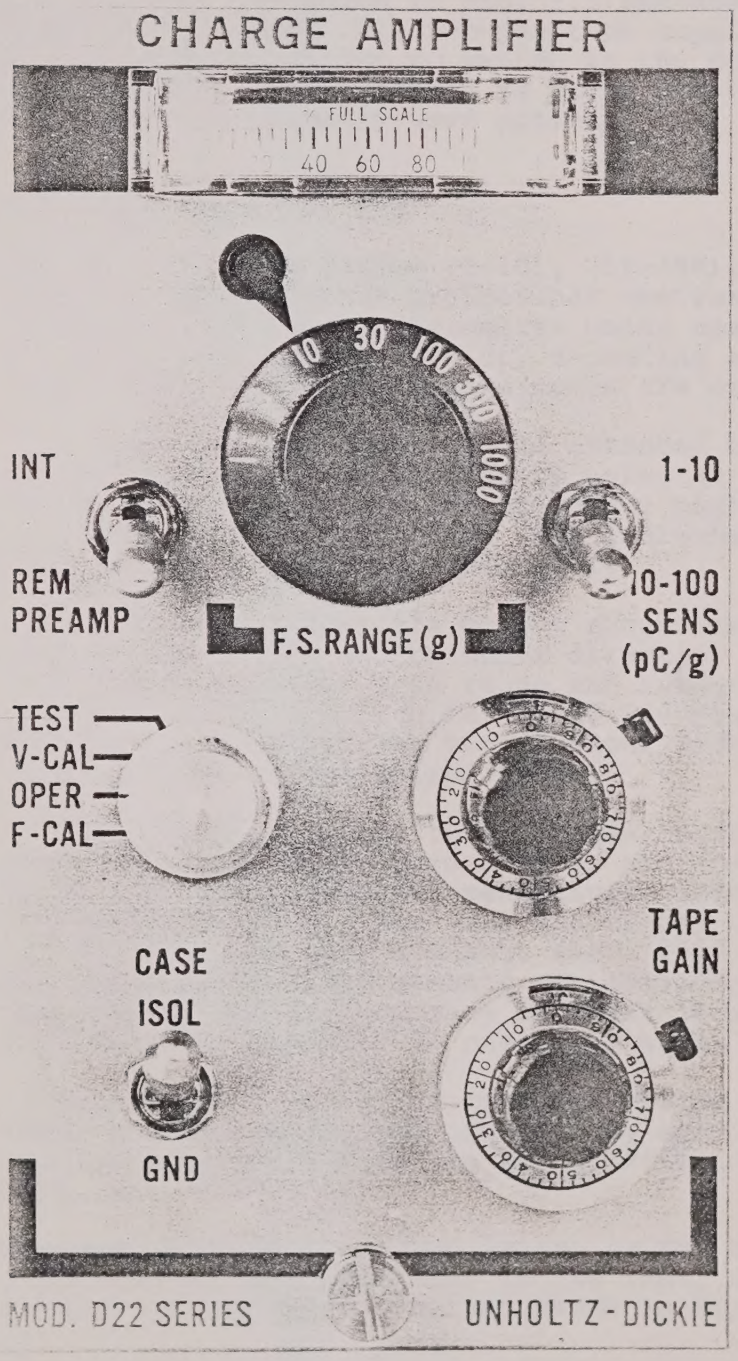


Fig. 2.1

Model D22PM Charge Amplifier

2. CONTROLS - CONNECTORS

The front panel controls are shown in Fig. 2.1. ~~and the rear panel details are shown in Fig. 2.2.~~ All two-position toggle switches are locking and must be pulled out to switch to the other position. The following descriptions are intended to cover all features of the series as well as the commonly-used options.

2.1 Front Panel Controls (Fig. 2.1)

2.1.1 SENSITIVITY RANGE SWITCH (1-10), (10-100). This two position toggle switch establishes the range for the sensitivity of the accelerometer being used. The units are pC/g, mV/g, or mV/1000 με, depending on whether the charge voltage or strain gage modes are employed.

Full scale output ranges can be extended by a factor of ten in the lower direction by using an accelerometer in the 10-100 range and intentionally placing the range switch in the 1-10 position. All indicated full scale range values are then divided by 10.

Similarly, the full-scale output ranges can be extended by a factor of ten in the upper direction by using an accelerometer in the 1-10 ragne and intentionally placing the range switch in the 10-100 position. This is especially useful for high-g shock work and all range values are multiplied by 10.

2.1.2 SENSITIVITY DIAL. This ten-turn dial with locking brake and potentiometer is used to set the significant figures of the transducer sensitivity within the ranges indicated in 2.1.1. The dial can always be set between 1.0 and 10.0 and also somewhat above 10.0 and below 1.0 depending on the requirements of individual users. The setting and reading accuracy is about 1% at 1.0, and 0.1% at 10.0 (one-half of one small scale division).

If either the internal or external charge converter is used, the charge sensitivity in pC/g specified on the accelerometer data sheet is set directly on the SENS. DIAL. and RANGE.

However, if remote voltage preamp or the high input-impedance voltage amplifier is the input device, the setting of the SENS. DIAL and RANGE in mV/g is given by:

$$S = S_A \frac{C_A}{C_A + C_C + C_{IN}} = \frac{Q_A}{C_A + C_C + C_{IN}}$$

Where:

S_A - data sheet voltage sensitivity for transducer (mV/g)

C_A - transducer capacitance (pF)

C_C - cable capacitance (pF)

C_{IN} - amplifier input capacitance (pF)

Q_A - charge sensitivity of transducer (pC/g)

For strain-gage inputs (D22PMR), the sensitivity of the gage is calculated by the following product:

GAGE SENS. = (gage factor)(resistance)(current)

$= FR_gI$ (mV/1000 microstrain)

2.1.3 FULL SCALE RANGE. A rotary switch having the full scale range values engraved on the skirt of the knob. For most manual ranging the switch has seven positions and the pilot light near the arrow indicates a power on condition.

For remote or externally-controlled ranging (Option E), the switch has five positions. Four of these are full-scale ranges for manual control and the fifth position, marked E, allows external control over the four values designated in the manual control positions.

For the autoranger (OptionA), the switch has six positions. The first five positions have the same functions as those for Option E, and the sixth position, marked A, allows fully automatic selection over the four ranges designated in the manual control positions.

2.1.4 TAPE GAIN. A ten-turn potentiometer with a turns-counting dial and locking brake, which varies the full-scale TAPE driver output from 0 to 100% of the specified value. Setting the TAPE GAIN at less than 100% (10 turns) causes a lower full scale output but allows a larger overdrive capability without clipping at the TAPE output. For example a setting of 20% will allow

peaks of 5 times the full-scale value to be reproduced without clipping for all except the highest full-scale range.

On occasion, the TAPE GAIN is controlled by a screwdriver-adjusted potentiometer, with no turns counting dial.

The full-scale output voltages are given on the flysheet of the manual.

2.1.5 GALV. GAIN (Option G) A ten-turn potentiometer with a turns-counting dial and locking brake, with a function identical to that of the TAPE GAIN except that it applies to the GALV. output.

2.1.6 CASE ISOL.-GND. A two-position toggle switch which selects the proper mode of operation with accelerometers which have the case isolated from the test specimen or the case common to the electrical ground at the test specimen. For the former case use the ISOL. position, and for the latter case, use the GND position.

The pilot light provides a convenient means for selection if the condition is not known. The state chart shows the possible combinations.

		CASE CONDITION	
		ISOL	GND
SWITCH POSITION	ISOL	ON	ON
	GND	OFF	ON

If the light remains on in both positions, choose the GND position for the switch. If the light is on only in the ISOL position, leave the switch in that position.

2.1.7 MODE SWITCH. A four-position rotary switch which selects modes of operation or calibration. The descriptions of the four positions follow.

For the D22PM and D22PMH instruments:

TEST - The shield of the transducer cable is connected to the OSC input. The oscillator voltage is fed to the charge converter through the capacitance of the cable and transducer. This provides a check of the cable and transducer integrity.

V-CAL - The OSC input is connected through a 1000 pF ±0.5% capacitor to the input of the charge converter. All outputs depend on the SENS. and RANGE SWITCH settings. A 1 pC/mV conversion is provided by the capacitor.

OPER. - The CHARGE input is connected directly to the charge converter and the OSC is disconnected.

F-CAL - The OSC input is connected so that the SENS. and F.S. RANGE settings are disabled and an input signal of 100 mV peak provides full scale indication for METER, GALV, and TAPE outputs.

The TEST and V-CAL positions are not operative when a REMOTE PREAMP is used. Calibration procedures with the remote preamplifiers is described in Section 4.1.

For the D22PMR instruments:

VOLT - The input preamplifier is connected as a high input impedance voltage preamplifier for piezoelectric transducers.

CHG - The input preamplifier is connected as a charge converter for piezoelectric transducers

F-CAL - The OSC input is connected so that the SENS and F.S. RANGE settings are disabled and an input signal of 100 mV peak provides full scale indication for METER and TAPE outputs.

S.G. - The input preamplifier is connected as a voltage preamplifier and accepts the input from a strain gage fed by a constant, but adjustable, current source. The S.G. CAL. switch is active in this position.

2.1.8 PREAMP. REM. - INT. A two position toggle switch. The REM. position is used for either the Model 22CA-2 or Model 11PA-2 remote preamp. The INT. position is used when the transducer is connected to the internal preamplifier in the Model D22 Series.

2.1.9 ACCEL DIFF - S.E. (D22PMH) A two-position toggle switch which is used to accommodate either single-ended (S.E.) or differntially connected accelerometers. The single-ended accelerometer has one side of the element common to the case. The differential accelerometer has the element isolated from the case which is characteristic of high-temperature accelerometers.

The S.E. position can be used for differential accelerometers, except that power frequency pickup due to poorly shielded junctions will probably be greater due to the unbalanced circuit for the S.E. connectors.

2.1.10 FILTERS The low-pass filter in the D22PM and D22PMR unit may be removed by removing the small plug-in capacitor board from card 12311 after the top-cover of the Model D22 has been removed.

However, separate low-pass (LP) and high-pass (HP) filter cards may be provided in the D22PMH. The accompanying front panel toggle switches either accommodate IN or OUT conditions.

2.1.11 CAL (S.G.) (D22PMR) This switch has three positions. The DYN position activates a multivibrator at 500 Hz which switches a 57 kilohm resistor across the strain gage input and simulates a peak-to-peak strain of 1000 με. The multivibrator is OFF in the central position for normal operation. The STAT position is a momentary on position which allows the operator to switch the calibration resistor across the strain gage.

2.1.12 S.G. CURR. (D22PMR) A five position switch, allowing the strain gage current to be set to 2, 5, 10, 20 or 40 mA ±1%. The current magnitude is indicated by the brilliance of the indicator LED directly above the potentiometers.

2.1.13 S.G. MON. (D22PMR) This is a miniature phone jack which allows the DC voltage and the waveform across the strain gage to be directly monitored.

2.2 Chassis Screwdriver Adjustments

These potentiometer adjustments are made from access holes located on top of the chassis and are appropriately marked. Adjustment is generally made only during periodic calibration checks.

2.2.1 ACC - For instruments with the SERVO output (Option S) this trimming potentiometer is used to adjust the output calibration constant to 10 mV/g. The adjustment is made before the METER and internal adjustment for full scale TAPE and GALV outputs are made.

For the basic instrument with no SERVO or GALV outputs, the ACC adjustment is set so that the full scale TAPE output is obtained for a calibration signal corresponding to the full scale value indicated by the F.S. RANGE switch.

2.2.2 F-CAL - The MODE switch must be in the F-CAL position before this adjustment is made, and 100 mV peak is applied to the OSC input. The F-CAL pot. is adjusted for full scale output at the TAPE output.

2.2.3 METER (Option M) The adjustment is made to provide full scale meter deflection when a calibration voltage corresponding to the full-scale value indicated by the F.S. RANGE switch is applied to the OSC input.

2.2.4 OSC (Option O) The adjustment is used to set the internal 1 kHz calibration oscillator signal to 100 mV peak. The internal oscillator signal can be monitored at the PATCH connector for this adjustment.

2.2.5 VEL. (Option I) The adjustment is used to set the calibration constant of the VEL. output to a fixed value between 100-110 mV-sec/in. This adjustment must be done after the ACC. adjustment.

2.2.6 DISP (Option II) The adjustment is used to set the calibration constant of the DISP output to a fixed value of 1.00 V/in. D.A. This adjustment must be made after the ACC. and VEL. adjustments.

2.2.7 LIN. DC (Option F) The adjustment sets the calibration constant of the LIN. DC output to a fixed value of 10V DC for full scale output. It must be made before the METER adjustment.

2.3 Internal Screwdriver Adjustments

These potentiometer adjustments can only be made by removing the top cover of the chassis. They have been carefully set at the factory and should only be readjusted if a malfunction is suspected. These adjustments are described for each printed circuit card.

2.3.1 DIAL-A-GAIN AMPLIFIER (12307) The BAL potentiometer is used to adjust the DC output of the card to a slightly positive voltage for a SENS. DIAL setting of 1.0 and no signal input. The voltage can be monitored on pin 4. The card may be put on an extender or the bottom cover may be removed to expose the connector pins.

The CURR ADJ. potentiometer is used to set the constant current excitation for the remote preamp at 4.0 mA. This can be measured by placing a milliammeter across the REMOTE PREAMP input.

2.3.2 DIFF AMP. - L.P. FILTER - TAPE (12311) The NULL potentiometer is used to adjust the ACC output of the instrument to a minimum when a test signal is inserted between the shell of the TRANSDUCER input connector and the shell of the ACC output connector. The CASE switch must be in the GND position. In this way rejection of ground difference potentials is accomplished.

The BAL potentiometer is used to adjust the DC voltage at the TAPE output to zero for direct coupling. The output may be monitored on pin 2, or at the rear TAPE connector. A card extender is sometimes required for this adjustment.

The GAIN potentiometer (when present) is used to adjust the TAPE OUTPUT to the specified full scale value for a TAPE GAIN setting of 100%, and a calibration voltage input equal to the full-scale value indicated by the F.S. RANGE Switch. The adjustment is always made after the ACC adjustment for the SERVO (10 mV/g) is done.

2.3.3 SERVO-METER (Options S-M-12373) The BAL potentiometer is used to null the output of the first stage of the converter (point A) for zero signal input.

The ZERO potentiometer is used to null the output of the last stage of the converter (point B) after the BAL adjustment is made. These adjustments are critical only when wide-range DC outputs are needed.

2.3.4 LOG DC (Option L - 12401) The 0 dB, 30 dB, and 60 dB potentiometers provide adjustments for the full scale output, gain, and low level linearity respectively of the logarithmic characteristic. See Section 4.8.

2.3.5 AUTORANGER COMPARATOR (Option A - 12427) The HIGH ADJ. and LOW ADJ. potentiometers provide adjustments for the levels at which the instrument switches to the next higher and the next lower ranges respectively. Normally the settings are at 105% and 8.5% of full scale, and must always be in excess of 20 dB.

2.4 Rear Panel Features

2.4.1 (ACCEL) CHARGE An insulated BNC connector for accepting the signal from a piezoelectric transducer. It is the input to the internal charge converter, and also to the internal high input-impedance voltage amplifier where the latter is provided. A Microdot 33-101 adapter is provided for compatibility with low-noise cable and a Microdot connector. The PREAMP switch must be in INT. position.

For use with high-temperature accelerometers (D22PMH), the two pin BNC (amphenol 31-223) is used to accept balanced inputs. An adapter is supplied for use with single-ended accelerometers (U-D Model S.E. Adapter).

2.4.2 SERVO (Option S) An insulated BNC connector providing an output voltage with the calibration constant of 10 mV/g.

2.4.3 TAPE An insulated BNC connector providing an output voltage of 10 V pk for inputs corresponding to the full scale value indicated on the F.S. RANGE switch and a peak current limited at ± 15 mA.

2.4.4 PREAMP An insulated BNC connector for accepting the two-wire connection (shield and center conductor) to the Model 22CA-2 or Model 11PA-2 external preamps. This connector is active in the REM position of the front panel PREAMP switch.

2.4.5 GALV. (Option G) An insulated BNC connector providing an output voltage of for inputs corresponding to the full scale value indicated on the F.S. RANGE switch. The output current is limited at ±100 mA.

2.4.6 LOG DC (Option L) An insulated BNC connector providing a DC output voltage proportional to the logarithm of the input amplitude. The calibration constant is 1.0 V/decade.

2.4.7 OSC A miniature phone jack for accepting an external calibration signal. If an internal oscillator (option O) is located within the module, it is automatically disconnected when the external signal is plugged into the OSC jack.

2.4.8 PATCH A miniature phone jack for patching the calibration signal on to the next channel. The PATCH jack for channel #1 is connected to the OSC jack for channel #2, etc. The mating phone plug is Switchcraft TINI-PLUG #780 for both jacks.

2.4.9 TF (Option T) A pair of INSULATED BNC CONNECTORS, one of which provides a 3 V peak full scale voltage for applying to the input of a Tracking Filter, and the other accepts the output of the Tracking Filter. THESE BNC CONNECTORS MUST BE JUMPERED TOGETHER WHEN A TRACKING FILTER IS NOT BEING USED.

2.4.10 RANGE CONTROL (Options E and A) An insulated two-pin BNC (Amphenol 31-223) for accepting an external two-wire binary-coded signal for controlling the full-scale range of the instrument when the F.S. RANGE is in the E position. The logic code for the four ranges is in the table below:

LOGIC 1:

(Option E) +15V max
(Option A) +5V max

LOGIC O:

TTL Specs

RANGE	PIN (31-223)	
	FEMALE	MALE
1000g	0	0
100g	0	1
10g	1	0
1g	1	1

Note the differences between the allowable maximum voltages for logic 1 for the E and A options.

2.4.11 RANGE MONITOR (Options E) An insulated two-pin BNC (amphenol 31-223) for providing a two-wire binary-coded signal to identify the full scale range of the instrument. The code table is identical to that for the RANGE CONTROL input.

2.4.12 S.G. See 3.7.3 D22PRM An insulated BNC for a two-wire connection to a 30 to 1000 Ω strain gage. It supplies constant current excitation to the gage and also supplies the AC signal to the input amplifier. The high input-impedance voltage amplifier is used for this option.

2.4.13 EXT GND - INT GND. A two position slide switch that connects the output circuit signal ground to the chassis in the INT GND position and leaves the signal ground floating in the EXT. GND. position.

If signal ground is common to chassis in the external instrumentation, the EXT. GND. position may generally be used. However, if the third wire in the power cord is not carried to the power line ground at the socket and the chassis is not electrically common to other

chassis in the system, the INT. GND. position should be used. The INT. GND. position should also be used if signal reference is not connected to chassis in the external instrumentation.

In a practical sense, the switch position should be used that shows the minimum amount of power frequency pickup with an oscilloscope monitoring the output(s) of interest.

2.4.14 VEL (Option I) An insulated BNC for providing a voltage proportional to velocity at 100 mV sec/in. Maximum output is ±10V at ±10 mA.

2.4.15 DISP (Option II) An insulated BNC for providing a voltage proportional to velocity at 1V/in. DA. Maximum output is ±10V at ±10 mA.

2.4.16 LIN. DC (Option F) An insulated BNC for providing a DC voltage proportional to the full wave average value of the acceleration. Output is 10 V DC for full scale inputs.

2.4.17 POWER A three-pin connector which mates with the 11RA rack adapter power strip or the individual line cord.

2.4.18 FUSE - Bussman GMW 1/2A.

3. OPERATION

All toggle switches must be pulled out to switch.

3.1 General Procedure

3.1.1 Internal or Remote Preamp (All Models)

Place the PREAMP switch on the REM position if the instrument is to be used with a remote two-wire preamp (Model 22CA-2 or 11PA-2) in the vicinity of the transducer. If there is a direct connection between the Model D22 and the transducer, use the INT position.

3.1.2 Single-Ended or Differential Accelerometers (D22PMH)

Place the ACCEL switch in the DIFF position for accelerometers in which the element is insulated from the case (usually high-temperature accelerometers) and in the S.E. position for accelerometers with single-conductor coaxial outputs. (One side of crystal common to case).

3.1.3 Input Connection Recommendations

D22PM, D22PMR

For single-ended piezoelectric transducers connect the transducer cable to the CHARGE/ACCEL input. It is recommended that low-noise, subminiature microdot cable is used whenever possible. Connection is made to the BNC by means of a Microdot 33-101 adapter. Standard RG/U cable instead of low-noise cable may be used, but extreme care in routing must be exercised, since it is often more than 100 times more sensitive to cable motion in generating electrical noise voltages (triboelectric effect).

D22PMH

A two-pin BNC (Amphenol 31-223) is the CHARGE INPUT connector and single-ended inputs may be made using the U-D Model SE Adapter (two-pin BNC to Microdot).

For differential accelerometers low-noise twisted-pair cable with a shield is recommended, since experience has shown that the triboelectric effect is at least an order of magnitude greater with untreated cable of this type. Triboelectric voltages are not cancelled greatly by the differential connection. Low-noise, shielded, twisted-pair cable can be obtained from the Vibrometer Corp., Los Angeles, Calif., and the Master Cable Corp., Monrovia, California. The cable is terminated by the Amphenol 31-224 connector which mates with the 31-223 on the D22PMR chassis.

D22PMR
Standard RG/U cable may be used for connecting strain-gages or other resistive devices to the SG input. The internal charge converter cannot be used for this application, and the internal high input impedance voltage amplifier must be used.

All Models
Use standard RG/U cable or other two-wire cable to connect the remote preamp to the PREAMP connector. Cable lengths up to 2000 feet can be used between the remote preamp and Model D22 Series. The low impedance level of the driving source makes the circuit insensitive to cable motion.

3.1.4 Other Front Panel Settings

CASE - ISOL or GND See Section 2.1.6
SENS. RANGE - See Section 2.1.1} Determined by Transducer
SENS. DIAL - See Section 2.1.2}
F.S. RANGE - To range value greater than highest measurement expected

3.1.5 Filtering
Check or otherwise make sure of the conditions of the low-pass filter on Board 12311. The filter is active if the small board containing three capacitors is plugged in. If front-panel switchable filters are provided (D22PMH), check the switch positions.

3.1.6 Output Connections
Connect the TAPE, GALV, SERVO, VEL, DISP, and/or LOG DC outputs to the readout or control equipment as required. See Section 2.4.13 for recommendation for setting the INT GND-EXT GND Switch.

3.1.7 Apply line power by plugging in the instrument cord or by applying power to the Model 22RA Rack Adapter housing the instruments. Make certain the front panel pilot light is ON. If the light is not on, consult Section 2.1.6 and then check the FUSE.

3.1.8 Adjust the TAPE GAIN and/or GALV GAIN as required. Remember that the dial setting provides a calibrated full scale output.

F.S. OUTPUT = (DIAL SETTING/10)(F.S. OUTPUT AT MAX GAIN)

3.1.9 Monitor and record test data as required.

3.2 Full Scale Calibration

3.2.1 Patch all channels to the channel with the internal oscillator (master) by connecting the PATCH jack of the master channel to the OSC jack of the next channel and continue this connection from channel to channel. If the internal oscillator is not present, designate a master channel and apply 100 mV peak at 100 Hz to the OSC jack of that channel. Six channels can be supplied by an internal oscillator (Option O).

3.2.2 Set MODE SWITCH to F CAL
TAPE GAIN to desired value (Section 2.1.4)
GALV GAIN to desired value (Section 2.1.5)
Monitor desired outputs

3.2.3 Apply line power and allow at least a minute for warm-up.

3.2.4 Check outputs for expected values.

3.3 Log DC Calibration (Option L)

3.3.1 The log DC output is usually used to plot acceleration amplitude vs frequency as in Fig 3.1 on a X-Y Recorder. With two Model D22 Series instruments ratios of two accelerations or of acceleration and force may be plotted.

3.3.2 Provide either log-log paper (2 x 3 or 3 x 5 are commonly used), or semilog paper (3 log x 70 linear) for recording.

3.3.3 On a range that will accommodate 1V/decade (20 dB), adjust the Y-ZERO control to locate pen at the top of the paper for direct amplitude recordings or near the middle for ratio recordings.

3.3.4 Provide the following connections and settings

LOG DC to (+) and (-) Y input
(-) Y input to GND Y input
} Amplitude Recordings

or

LOG DC (#1) to (+) and GND Y input
LOG DC (#2) to (-) and GND Y input
} Ratio Recordings

and

MODE Switch to F CAL
OSC input to 100 mV-peak (both channels)
SENS. to 10 pC/unit
F.S. RANGE to 100

Allow at least five minutes warmup.

3.3.5 For amplitude recording adjust Y-ZERO control slightly for conditions above to align full-scale output with top division of paper.

3.3.6 Change MODE from F-CAL to V-CAL (D22PM, D22PMH) for -one decade or -20 dB change. Adjust Y-GAIN for appropriate -20dB or decade change on graph paper. For D22PMR, change the oscillator input to 10 mV p and leave MODE on F-CAL.

3.3.7 Repeat 3.3.5 and 3.3.6

3.3.8 For ratio recordings and alternate conditions in 3.3.4 adjust Y-ZERO control to align 0 dB on unity ratio point with a central paper division. For D22PMR use 10 mV p and F-CAL to provide the 20 dB changes in the following sections.

3.3.9 Change MODE on channel #1 from F-CAL to V-CAL (-20 dB or -1 decade change). Adjust Y-GAIN for -20 dB change.

3.3.10 Change MODE on channel #2 from F-CAL to V-CAL (+20 dB or +1 decade change). Adjust Y-ZERO if necessary.

3.3.11 Change MODE on channel #1 to F-CAL (+20 dB or +1 decade change). Readjust Y-GAIN for +20 dB change if necessary.

3.3.12 Change MODE on channel #2 to F-CAL and repeat 3.3.8 to 3.3.11.

3.3.13 For additional dynamic range for ratio recording use the U-D Model MAC-8 or the Model ACS-6 with the Servo control to let both plotted quantities vary in a controlled fashion rather than control one and let the other vary. In this fashion plotting range can be increased from 60 dB to 120 dB.

3.4 Integrity Test For Input Cable and Transducer (D22PM, D22PMH)

This test can be carried out with the transducer operating with the internal change converter and for accelerometers the cases of which are ISOLATED from signal reference at the test site. For DIFFERENTIAL accelerometers one side is automatically connected to the CASE for the test.

3.4.1 Provide the following connections and settings:

Connect input transducer (Section 3.1.3)

Provide 100 mV peak at OSC jack if option 0 is not available.

SENS.	to	10.0
F.S. RANGE	to	10
MODE	to	V-CAL

Apply power, allow at least a minute warmup.

3.4.2 Check full scale output voltage (V_{FS}) at either TAPE or GALV. OUTPUT.

3.4.3 Switch MODE to TEST. Record OUTPUT voltage (V_T) and F.S. RANGE (R_T). It may be necessary to change the range.

3.4.4 Total capacitance of cable and accelerometer is given by:

$$C_C + C_a = \frac{R_T \; V_T}{10 \; V_{FS}} \; 1000 \text{ pF}$$

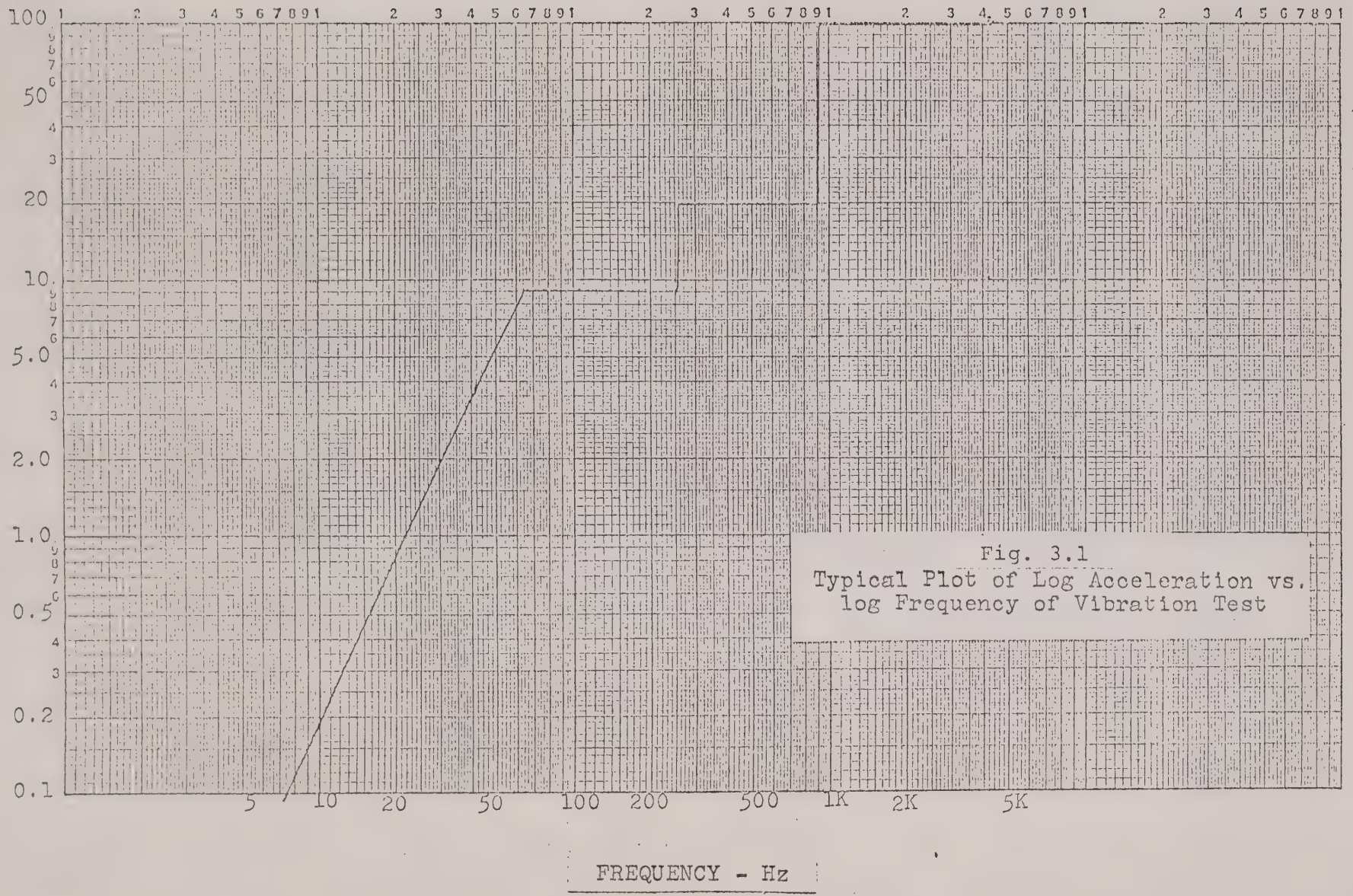


Fig. 3.1
Typical Plot of Log Acceleration vs. log Frequency of Vibration Test

3.5 Strain-Gage Operation (D22PMR)

3.5.1 Connect the strain gage to the S.G. input. Low-noise cable is not necessary, although coaxial cable best suits the BNC input connector. Switch the MODE to S.G., PREAMP to INT.

3.5.2 Determine the maximum possible current to excite the strain gage. This is usually limited by the maximum allowable dissipation of the strain gage although for high resistance gages (above 350 ohms) the maximum allowable DC voltage (7V) for the Model D22PMR may be the limiting factor. For metal-mounted gages a power dissipation of 10 watts/in.^{2} can be used.

3.5.3 Select one of the five values provided for S.G. CURRENT. Note that this selection is accurate to ±1%

3.5.4 Compute the sensitivity of the gage by performing the following multiplication. The result may be recorded and kept much like an accelerometer sensitivity.

GAGE SENS. = (gage factor)(resistance)(current)

= FR_gI (mV/1000 microstrain)

Note that each factor in the above product is accurately determined. For example, F = 2.1; R_g = 120 ohms, and I = .040 A yields

GAGE SENS. = (2.1)(120)(.040) = 10.0 mV/1000με

3.5.5 The gage sensitivity as calculated in 3.5.4 is set directly by the SENS. DIAL and SENS. RANGE switch. The Model D22PMR is then fully calibrated for use.

3.5.6 Set the F.S. RANGE switch to the desired value for making the required measurements.

3.5.7 The DC voltage or the dynamic voltage directly across the strain-gage and connecting cable may be monitored at any time by means of a miniature phone jack inserted into the MON. jack on the front panel.

3.6 Strain Gage Calibration (D22PMR)

In the DYN position of the S.G. CAL switch, a precision resistor is switched across the strain gage (and connecting cable) by means of a multivibrator switch. A square wave is produced at the input, and a check on calibration is provided.

3.6.1 The peak-to-peak voltage for the square wave input, as measured at the S.G. MON jack is

$$V_{pp} = IR_g^2/(R_g + R) \simeq IR_g^2/R$$

In terms of strain this gives:

$$\mu\varepsilon_{pp} = (V_{pp}/FR_gI) \times 10^6 \simeq (R_g/FR) \times 10^6$$

For example, F = 2.1; R_g = 120 ohm; I = .040 A and R = 57.2 k ohms yields

V_{pp} = 10.0 mV $\mu\varepsilon$ = 1000 microstrain

3.6.2 The calibration may also be checked by monitoring the TAPE OUT. The peak-to-peak output excluding transients due to the Butterworth filtering is dependent on the full scale range $\mu\varepsilon_{FS}$ and is (for 1V peak F.S. output)

$$V_{pp} = ((R_g/F\ (R_g + R)\ (\mu\varepsilon_{FS})\ )) \times 10^6$$

The meter on the D22PMR is calibrated in terms of peak sine waves but responds to the full-wave average value. For the square wave calibration signal it indicates:

$$V_M = \frac{\pi}{4} V_{ppo} = .785\ V_{ppo}$$

Other AC meters calibrate in terms of rms sine inputs but responding to full-wave average values indicate .707 of V_M. For the example in 3.6.1 and for the 1000 $\mu\varepsilon$ full scale range, we have

V_{pp} = 1.00 V and V_M = 78.5% of full scale

3.7 Remote Range Control (Options E and A)

3.7.1 Place RANGE switch in E position. Connect the two range control lines to the RANGE CONTROL input (amphenol 31-223). The mating connector is the Amphenol 31-224. Arrange to supply logical inputs according to the code in 2.4.10.

3.7.2 The line loading for Option E is approximately 10K and for Option A, 3 TTL unit loads. Should lower loading be desired for Option A, the indicator light driving circuit may be disabled by removing the connections to pins 3 and 4 of the Autoranger Logic Board (12425). This makes the line loading the same as that for Option E.

3.7.3 Connect the RANGE MONITOR output to the desired monitoring equipment. The connector type is the same as that for the RANGE CONTROL. For the RANGE SWITCH in one of the four manual positions, 10 mA/line can be supplied for logic 1 and each line can sink 20 mA for the logic 0 condition. For the RANGE switch in the E position, the line output capability is determined by the control source. For the RANGE switch in the A position, see Section 3.8.1.

3.7.4 Due to the large output capability of the RANGE MONITOR manual control of range for one channel can be used to control the range for at least 11 other channels. For this operation, use manual range positions for master channels. Use E range position for slave channels. Connect RANGE MON. for master channel to RANGE CONT. for all slave channels.

3.8 Automatic Range Control (Option A)

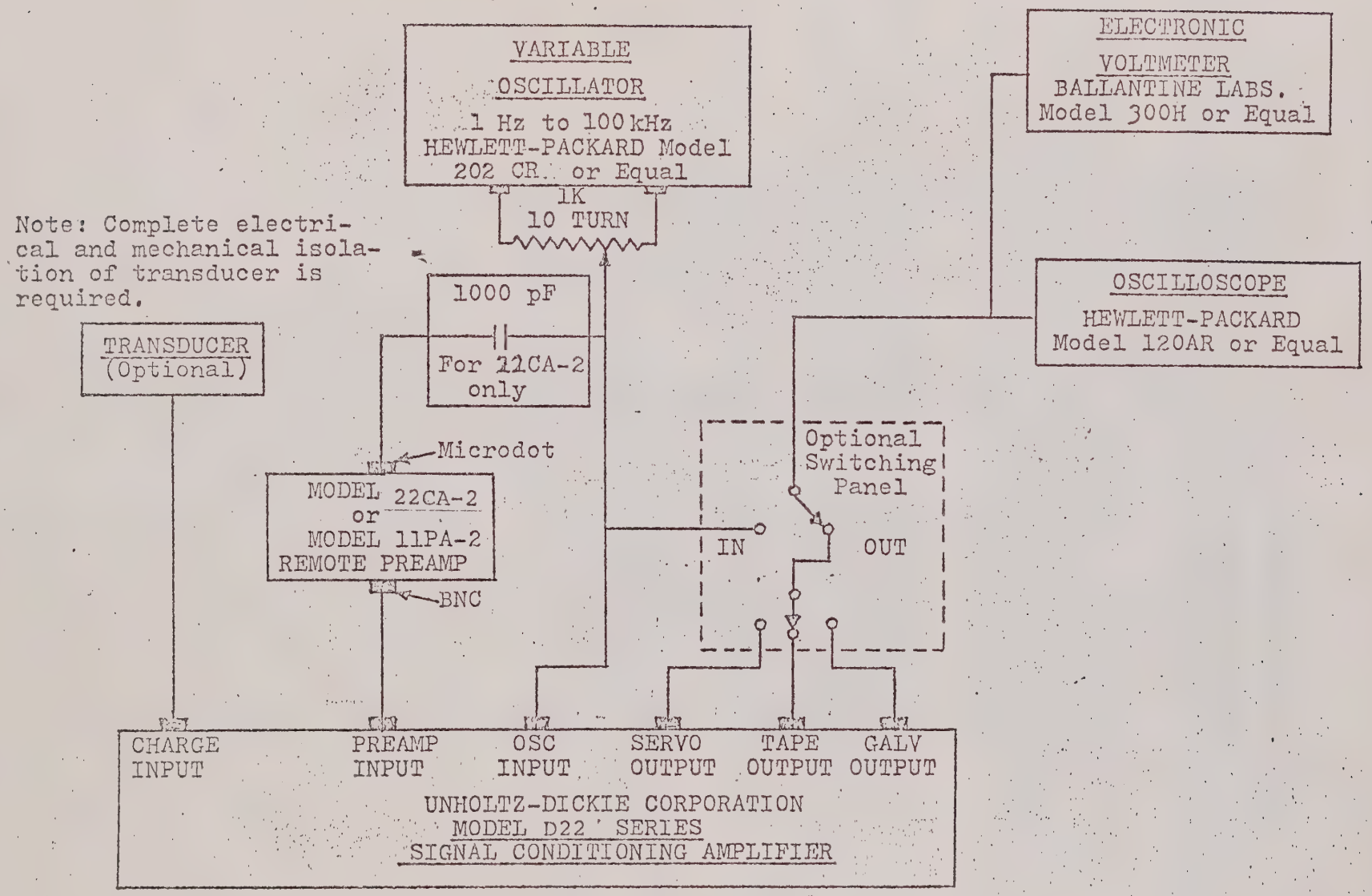
3.8.1 Place the RANGE switch in the A position. Monitor the range as necessary by means of the RANGE MON. connector. The line driving capability in the A position from the RANGE MON connector is 4 TTL unit loads.

3.8.2 Record data as desired. Note that the LED indicators give a visual indication of F.S. RANGE. Should the LOG DC output be supplied, the full scale output depends on the range. Should servo control be desired from the 10 mV/g SERVO output, it is probably desirable to leave the F.S. RANGE switch in one of the manual positions (100 g).

3.8.3 Automatic range switching in one (master) channel may be used to control the range in other channels by means of the following procedure. Should more than one slave channel be desired, disconnect the light driving circuits in the slave channels according to the instructions in 3.7.2, and at least 11 slave channels may be accommodated.

Put master channel RANGE in A position. Put slave channel(s) RANGE in E position. Connect RANGE MON. for master channel to RANGE CONT. for slave channels.

Note that the LED'S for the master channel indicates the range for all channels.



MODEL D22 SERIES CHECKOUT INSTRUMENTATION BLOCK DIAGRAM
Figure 4.1

4. CALIBRATION - CHECKOUT

4.1 Gain Calibration

4.1.1 Instrumentation

Connect the instrumentation as shown in Fig. 4.1. A precision step-attenuator such as a Gertsch Ratio-Tran Model RT-7C, or equal, can be inserted between the oscillator and D22 Series instrument to facilitate range switch accuracy checks.

The calibration capacitor for use with the Model 22CA-2 must be shielded and connected to the input of the Model 22CA-2 by means of a low-noise shielded cable.

The use of the V-CAL mode for calibration (D22PM, D22PMH) automatically places the input charge converter in a single-ended connection, even though differential or balanced operation is available for use with transducers. A means for differential gain calibration is included in Section 4.7.

For the (D22PMR) connect the oscillator to the ACCEL input and switch the MODE to VOLT.

Always use the oscilloscope to monitor waveform purity, avoid ground loops between input and output circuits, and follow recommendations in 2.4.13 for the INT. GND. EXT. GND. switch.

4.1.2 Charge Input

It is not necessary to have a cable or transducer connected to the CHARGE input, the connection may be covered with a shielded cap but the center conductor(s) cannot be shorted to the shield.

4.1.3 Instrument Settings

PREAMP	-	INT.
MODE	-	V-CAL (VOLT for D22PMR)
CASE	-	ISOL.
FILTERS	-	OUT (if applicable)
TAPE/GALV GAIN	-	10 TURNS (MAX)
SENS	-	10 (RANGE 1-10, TURNS = 10)
F.S. RANGE	-	10 g
Audio Oscillator	-	100 mV peak (70.7 mV rms) @ 1 kHz (Use ACCEL input for D22PMR)

4.1.4 SERVO (10 mV/g) Output (Option S)
If the SERVO option has not been provided begin with Section 4.1.5
Attach CRO and ACVM to SERVO connector
Adjust ACC potentiometer to provide 100 mV peak
70.7mVRMS

4.1.5 TAPE, GALV., AND Meter Outputs
Attach CRO and ACVM to TAPE and/or GALV connector. If the SERVO adjustment in 4.1.4 has been made, adjust GAIN potentiometer in DIFF. AMP-TAPE-L.P. FILTER board (12311) for the specified full-scale value at TAPE output. Check GALV. output for all full scale value.

If there is no SERVO output, adjust ACC potentiometer for specified full scale output at TAPE and/or GALV outputs.

Adjust METER potentiometer to provide 100% full scale meter indication. If linear DC output (Option F) is offered, go to 4.1.7.

4.1.6 F-CAL Adjustment
Change MODE switch to F-CAL position, and apply voltage to OSC input.

Adjust F-CAL potentiometer for exactly full scale output from TAPE output. Changing F.S. RANGE or SENS settings should not affect TAPE output.

4.1.7 LIN. DC Adjustment
Adjustment LIN DC potentiometer on meter servo board to provide exactly 10 V DC at LIN. DC output. Return to 4.1.5 and adjust METER output as indicated.

B. on center
B/Y on side

4.2 Sensitivity Dial Offset

This adjustment has been set carefully at the factory and should not require routine adjustment.

4.2.1 Use settings in 4.1.3

4.2.2 Adjust TAPE GAIN to provide 1.00 V pk ± 1% (.707 VRMS)

4.2.3 Decrease oscillator voltage to 10 mV peak. Set SENS DIAL at 1.00. 7.07

The output voltage should be 1.00 V pk ± 1%. (.707 VRMS)

4.2.4 If the output voltage is too high (low) in 4.2.3 turn SENS. DIAL CCW until the stop is reached. Note the reading on the dial. Loosen the set screw on the knob and decrease (increase) the dial setting by one minor division for each 2% error in 4.2.3. Lock the setting, replace the dial and tighten the set screw, taking care not to move the shaft off the CCW stop.

One adjustment is usually sufficient if the offset measurement is inaccurate by only a few percent.

4.3 Maximum Output

4.3.1 Instrument Settings

SENS	-	10 (RANGE1-10, TURNS = 10)
F.S. RANGE	-	1000 (1k) g
PREAMP	-	INT.
MODE	-	V-CAL (VOLT for D22PMR)
TAPE/GALV GAIN	-	MAX. (10 TURNS)
CASE	-	ISOL
FILTERS	-	OUT (if applicable)
Audio Oscillator	-	10 V peak (7.07 V rms @ 1 kHz (Use ACCEL input for D22PMR) (5 vp 3.535 VRMS)

4.3.2 The TAPE, GALV, and/or SERVO output signals should not show clipping or distortion at the peaks.

4.4 Full Scale Range Switch Accuracy

4.4.1 With the settings in 4.3.1 adjust the audio oscillator for an output of 1.00 V pk. The TAPE output should be 1.00 V pk at full CW rotation. If less than 1 V peak output represents full scale output, adjust SENS to provide 1 V pk at the TAPE output.

4.4.2 Adjust oscillator input according to the following table for associated F.S. RANGE settings. The Gertsch Ratio-Tran is a helpful device for this procedure. The TAPE output should be 1.00 V pk ±1% for all F.S. RANGE settings.

Oscillator (V pk)	F.S. RANGE
1.00 (.707 rms)	1K
.300 (.212 rms)	300
.100 70.7 mVrms	100
.030 21.2 mVrms	30
.010 7.07 mVrms	10
.003 2.12 mVrms	3
.001 .707 mVrms	1

4.5 Frequency Response

4.5.1 Instrument Settings - same as 4.1.3 except:

SENS - 1.00

F.S. RANGE - 1000 g

Audio Oscillator - 1.00 V pk

Adjust TAPE GAIN for 1.00 V pk @ 1 kHz (.707VRMS)

4.5.2 The percentage variations of the TAPE OUT at other frequencies are given in the following table:

FREQ (HZ)	2	5	10	20	2 k	4 k	30k
NO FILTERS	±5%	±2%	±1%	±1%	±1%	±1%	±5%
2 kHz LP FILTER	*	*	*	*	±2%	∿-3dB	-
Hz HP FILTER					*	*	*

*See appropriate row

Below 10 Hz, input and output measurements should be made on a direct-coupled oscilloscope

4.6 Noise

The measurements are made at high instrument gains, with a full scale output for the D22PM and D22PMH of 10 V peak, and a full scale output for the D22PMR of 1 V peak.

4.6.1 Instrument Settings:

SENS - 1.00 (1-10 range)

F.S. RANGE - 1 g

PREAMP - INT

MODE - OPER (D22PM, D22PMH); CHARGE (D22PMR)

TAPE GAIN - MAX CW (10 TURNS)

CASE - ISOL

FILTERS - IN (D22PMH only)

ACCEL - SINGLE ENDED (D22PMH only)

Connect 100 ft low noise cable and a nominal 10 pC/g transducer to the CHARGE input or 4000 pF of shielded capacitance.

The maximum noise at TAPE or OUT connector should be 110 mV rms for the D22PM and D22PMH and 11 mV rms for the D22PMR. (.011 pC RTI).

4.6.2 With a Model 22CA-2 or Model 11PA-2 remote preamp, change the PREAMP switch to REM and connect a shielded 1000 pF capacitor across the input to the remote preamp. With the remaining settings in 4.6.1, the output noise should be

	D22PM with D22PMH	D22PMR	RTI
Model 22CA-2	80 mV rms	8 mV rms	(.008 pC rms)
Model 11PA-2	400 mV rms	400 mV rms	(40 μV rms)

4.6.3 For the D22PMR only, put the mode switch in the S.G. position, and connect a 120 Ω 1% resistor to the S.G. input. Place the S.G. CURR. in the 40 mA position. Other settings:

RANGE - 10 με

SENS. - 10 (10 Turns, 1-10 Range)

TAPE GAIN - Full CW (10 Turns)

The noise should be less than 50 mV rms, which is less than 0.5 με RTI.

4.7 Differential Gain Calibration (D22PMH)

4.7.1 Instrumentation

Provide those instruments shown in Fig. 4.1 and a special calibration box shown in Fig. 4.2

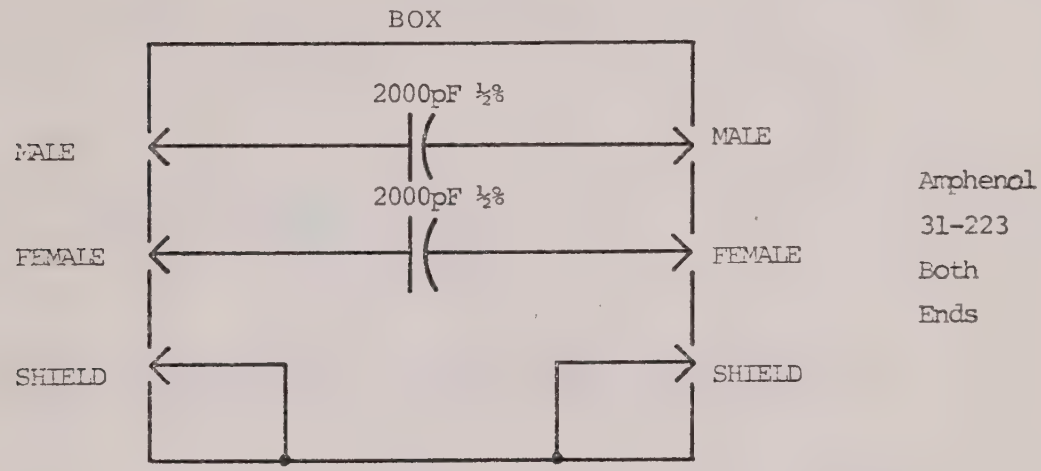


Fig. 4.2 Calibration Box

Connect the capacitor box to the CHARGE input of the Model D22 as shown in Fig. 4.3. The oscillator output must be capable of being floated above chassis. It may be necessary to use an isolation transformer if this is not possible.

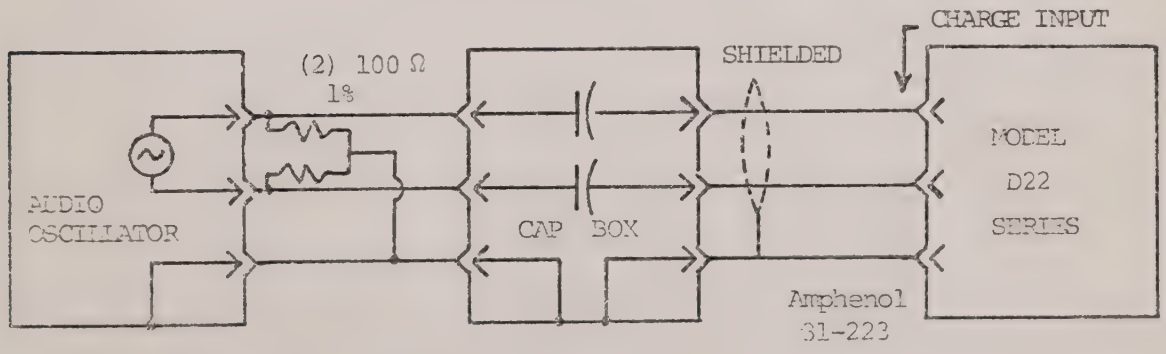


Fig. 4.3 Equipment Setup-Input

4.7.2 Instrument Settings:

PREAMP	-	INT.
MODE	-	NORM.
CASE	-	ISOL.
ACCEL	-	DIFF.
TAPE GAIN	-	MAX. GAIN (10 Turns)
SENS	-	10 (Range (1-10) Turns = 10)
F.S. RANGE	-	10
Audio Oscillator	-	50 mV peak (35.4 mV rms) from each balanced terminal to the shield. If the voltages are not quite equal, make the sum 100 mV peak @ 1 kHz.

4.7.3 TAPE/GALV output should be the full scale value ±1%. The precision components in the charge converter should provide these calibration checks to be in tolerance if the adjustments in 4.1 have been properly made.

4.8 Log DC output (Option L)

4.8.1 Instrument Settings:

PREAMP	-	INT.
MODE	-	V CAL (D22PMH, D22PM) or VOLT (D22PMR)
CASE	-	ISOL
TAPE/GALV GAIN	-	10 TURNS (MAX)
SENS	-	10 (1-10 range, 10 T)
F.S. RANGE	-	1000 g

4.8.2 Monitor the input of the LOG DC board (pin 1) with a digital DC Voltmeter. With zero oscillator input (OSC jack shorted), check the BAL. and ZERO adjustments of the METER-SERVO board (12373) as noted in 2.3.3. A null less than 1 mV DC should be obtained.

4.8.3 Connect the digital DC voltmeter to the LOG DC output connector. Allow several minutes warmup.

4.8.4 Apply 7.07 V rms at 1000 Hz to OSC input (D22PM, D22PMH) or ACCEL (D22PMR) Adjust 0 dB potentiometer on LOG DC card to obtain an output of 0 mV ±10 mV.

4.8.5 Apply .223 V rms. Adjust 30 dB potentiometer to obtain an output of -1.50 V ±10 mV.

4.8.6 Apply 7.07 mV rms. Adjust 60 dB potentiometer to obtain an output of -3.00 V ±25 mV.

4.8.7 Repeat 4.8.4 through 4.8.6 if necessary. The full-scale output is set by 4.8.4. The gain of the LOG DC converter is set by 4.8.5. The offset voltage of an op. amp. is balanced by 4.8.6.

4.9 VEL Output (Option I)

4.9.1 Instrument Settings: Same as 4.8.1

4.9.2 Apply .0977 V rms 60 Hz to OSC (D22PMH, D22PM) or to ACC IN (D22PMR)

4.9.3 Adjust VEL and measure 1V rms at VEL OUT for 100 mV-sec/in sensitivity. This must be done after calibrating the 10 mV/g output.

4.10 DISP Output (Option II)

4.10.1 Instrument Settings: Same as 4.8.1

4.10.2 Apply .1839 V rms 60 Hz to OSC (D22PMH, D22PM) or to ACC IN (D22PMR)

4.10.3 Adjust DISP and measure 0.1 V rms at DISP OUT for 1 V/in DA sensitivity. This must be done after section 4.9.

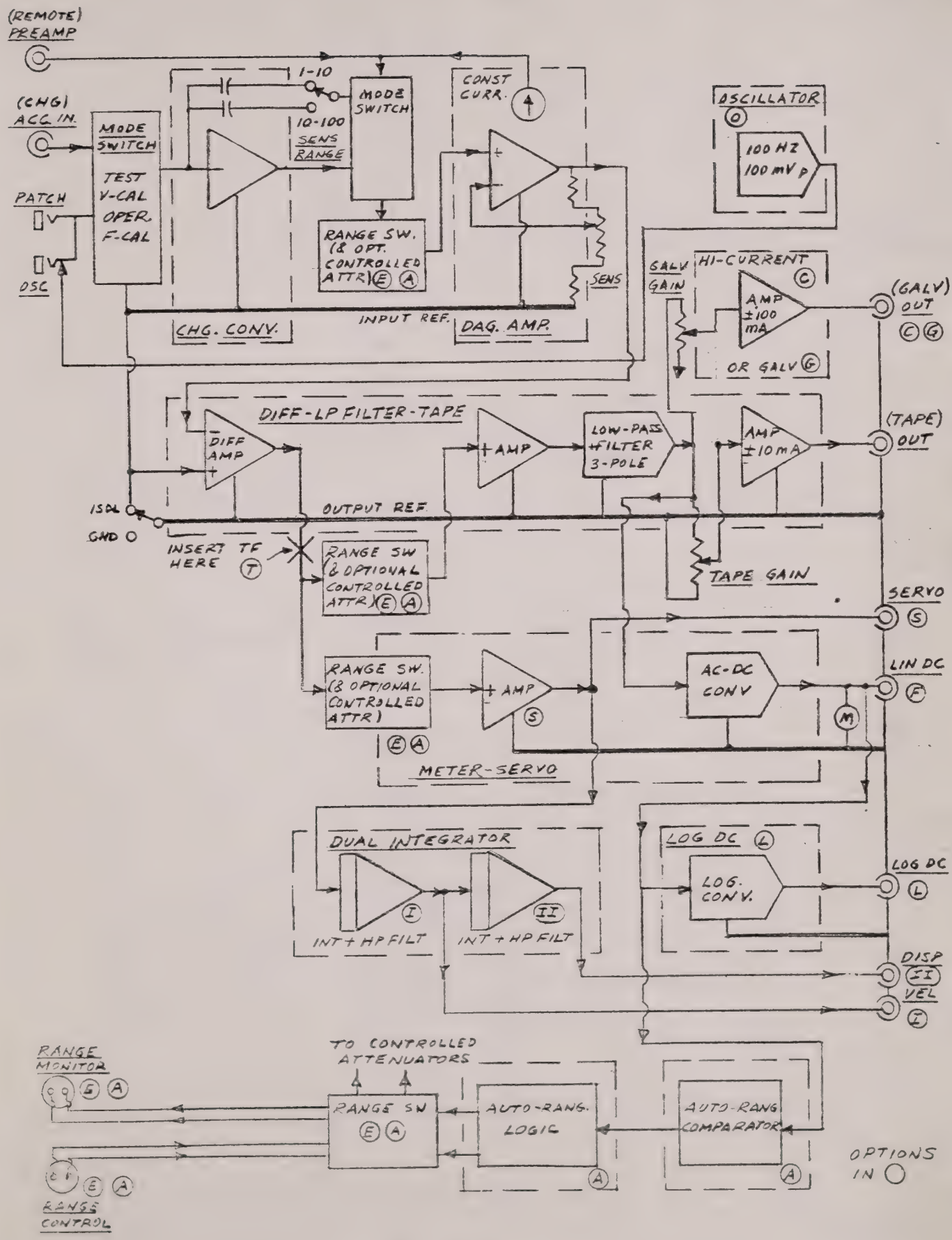
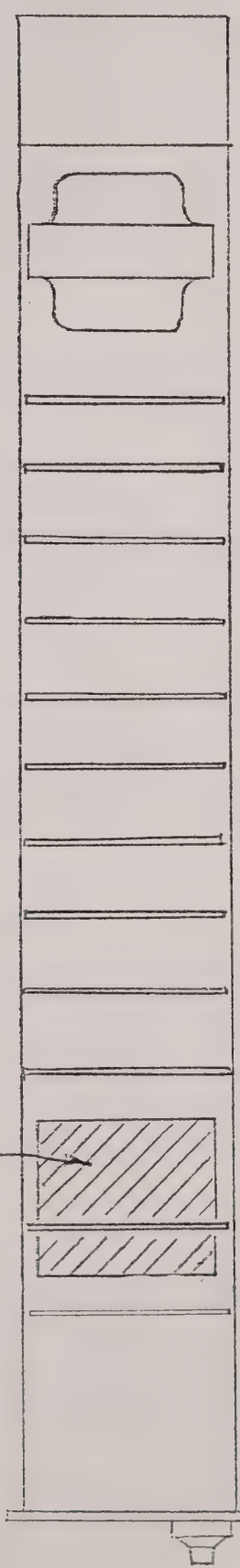


FIG. 5.1
BLOCK DIAGRAM
MODEL D22PM WITH OPTIONS

FIG 5.2 CHASSIS LAYOUT



OPTIONS SERVED

HI-CURRENT DRIVER — G, C

T.F. - SERVO FILTER - OSC — T, S, O

DUAL INTEGRATOR — I, II

LOG DC — L

METER-SERVO — S, F

Components on all cards face rear

Metal deck insulated from chassis - Kept at input reference (charge conv. cover removed)

MODEL
D22PM(GSLTOIF

5. MAINTENANCE-SERVICING

5.1 Block Diagram

As an aid to understanding the operation of the Model D22 Series a simplifier schematic/block diagram is shown in Fig. 5.1. The complete schematic is found in Dwg. No. C12496.

5.2 Chassis Layout

The layout of the chassis cards is shown in Fig. 5.2. The view is from the top of the chassis with the top cover removed.

5.3 Access for Servicing

Although normal calibration and checking procedures may be accomplished from the outside, as noted in Section 4, it may occasionally be necessary to inspect the printed circuit cards or the connector wiring.

The top cover may be taken off by first removing three screws on the top of the chassis at the front and rear. The cover may then be pulled up and off. To replace, slide the sides of the top cover in the groove formed by the bottom cover and the card tray and replace the screws. The removal of the top cover gives access to the printed circuit cards (except the charge converter card).

5.4 Charge Converter Card

The connector for the charge converter card is mounted on a metal panel which is electrically isolated from the chassis. A bottom shield, which partially covers the connector contacts, and a top shield, which covers the charge converter card and is attached to the card by standoffs, are mechanically attached to the insulated mounting plate by two screws. These screws may be removed from the underside of the card tray. The mounting plate and both shields are electrically common to the input reference.

The assembly not only provides the necessary rigidity for the charge converter card but also shields critical portions of the circuit from electrical pickup.

The charge converter card and the attached shield are removed by first removing the two shield mounting screws and then pulling the assembly from the connector. The card and upper shield are separated by removing two screws from the side of the shield.

5.5 Voltage Measurements

Table 5.1, which follows, gives typical voltage throughout the instrument. Large deviations usually indicate a malfunction.

It is assumed that no accelerometer is connected and the SHIELD SWITCH is in the ISOL position. Use a 20,000 ohm/volt multimeter for the measurements (Simpson Model 270; Triplett Model 630-NA)

CARD	TERMINAL(S)	VOLTAGE
OUTPUT POWER SUPPLY	1-2	20 ± 4 V AC rms
OUTPUT POWER SUPPLY	1-3	20 ± 4 V AC rms
OUTPUT POWER SUPPLY	10-6 (REF)	14.5 ± .5 V DC
OUTPUT POWER SUPPLY	9-6 (REF)	14.5 ± .5 V DC
INPUT POWER SUPPLY	1-2	25 ± 4 V AC rms
INPUT POWER SUPPLY	1-3	25 ± 4 V AC rms
INPUT POWER SUPPLY	10 *	21 ± .5 V DC
INPUT POWER SUPPLY	9	21 ± .5 V DC
CHARGE	H	0 ± .010 V DC
DIAL-A-GAIN AMPLIFIER	8	0 ± 0.5 V DC
DIFF-LP FILTER - TAPE	3	0 ± 0.5 V DC
HIGH-PASS FILTER	1	.2 ± .2 V DC
VELOCITY INTEGRATOR	1	0 ± .001 V DC
HIGH-CURRENT DRIVER	1	0 ± .001 V DC
HIGH-CURRENT DRIVER	10-8	12 ± 2 V AC rms
HIGH-CURRENT DRIVER	9-8	12 ± 2 V AC rms

*All DC Voltage Measured Relative to Pin 6

TABLE 5.1

5.6 Servicing Malfunctions

The detailed calibration and checkout procedures in Section 4 and the voltage measurements in Section 5.5 should be of great help in pinpointing possible trouble. In addition, standard signal tracing techniques proceeding generally from input to output and making use of the oscilloscope are of great help.

The printed circuit cards are also removable, which helps locate short-circuit malfunctions.

If replacement of any component is necessary on a printed circuit board, the excess solder at the points of insertion should first be removed by either a soldering iron and a desoldering wick (Dri-wick-American Electrical Heater Co.) or a desoldering bulb (Ungar #7805 Solder-Off Bulb). Combinations of soldering irons and bulbs are also available (Ungar Model 7800 Hot-Vac Tool).

Removal of integrated circuits is best accomplished by using a special soldering iron tip designed to fit around the IC pins and an extractor. The excess solder around the insertion points is removed by the method of choice, and the IC pins are then straightened. The card is then clamped in a bench vise, the pins are heated with the special soldering iron tip (Princess 6902 Handle 6918 Heat Capsule, and 6948 tip) and the integrated circuit is pulled out with the extractor.

When the soldering wick is used, the integrated circuit may often be pried out carefully without the use of the special soldering tool.

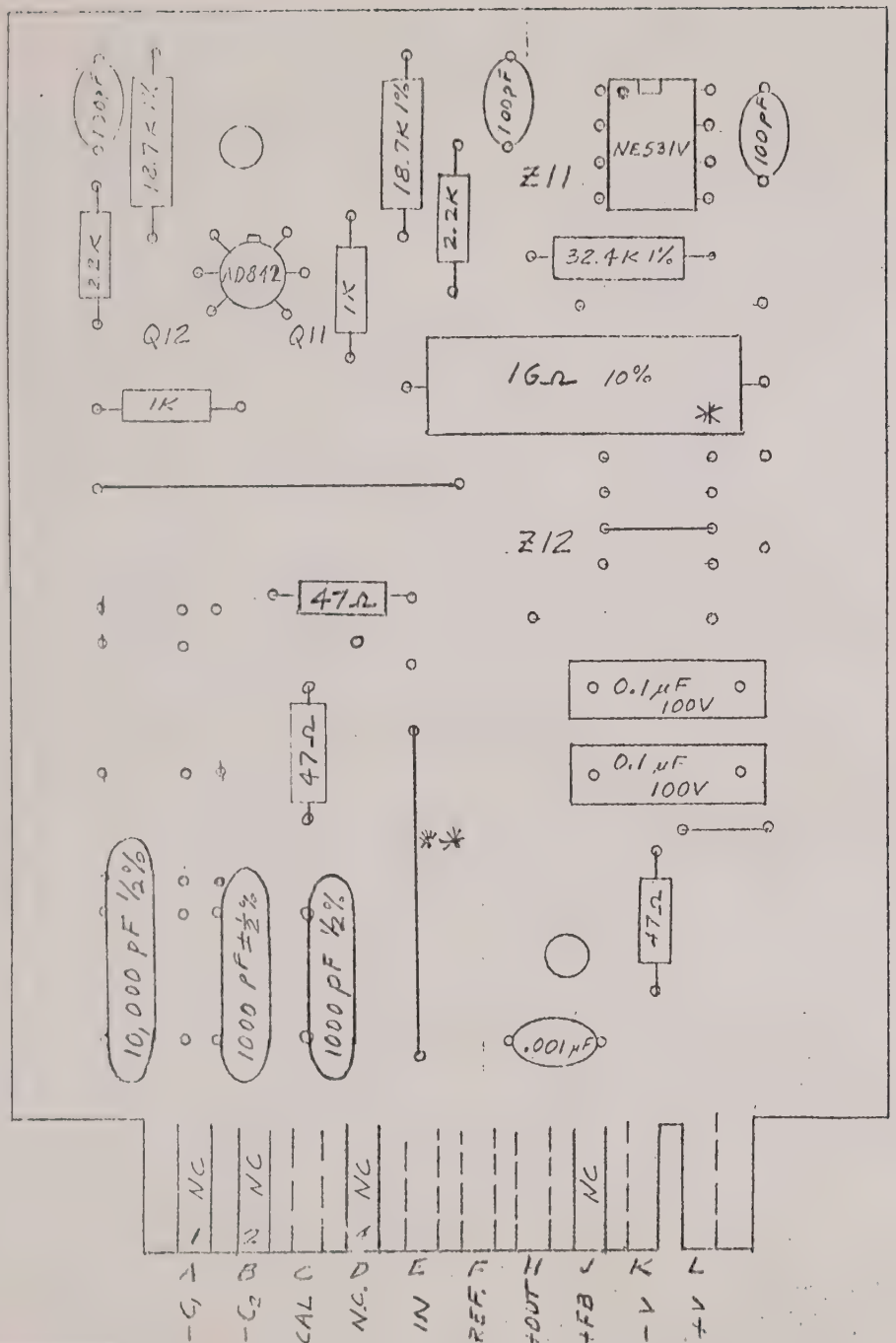
Care should always be taken in removing components to avoid delamination of the conductor from the printed-circuit card.

5.7 Component Location

Figures 5. through 5. show the component layout for each of the circuit boards.

5.8 Following is ordering information for integrated circuits, semiconductors, and other critical components used in the Model D22. Other resistors and capacitors are widely available from many sources.

PART NO.	DESCRIPTION	MANUFACTURER
NE531V	I.C. Op. Amp	Signetics
LM301AN	I.C. Op. Amp	National, Raytheon
ICL8007C	I.C. FET Op. Amp.	Intersil
AD540J	I.C. FET Op. Amp.	Analog Devices
UGA7723393	I.C. Voltage Regulator	Fairchild (μA723)
AD841	Dual FET	Analog Devices
DG200BA	Dual SPST CMOS Gate	Siliconix
MC1439/1539	I.C. Op. Amp.	Motorola
SN7400N	Quad 2 input Nand Gate	Texas Inst.
SN7404N	Hex Inverters	Texas Inst.
SN74191N	Up-Down Counter	Texas Inst.
SN7420N	Dual 4 Input Nand Gate	Texas Inst.
LM311	Comparator	National
T1S92	Si. NPN	Texas Inst.
T1S93	Si. PNP	Texas Inst.
2N4922	Power NPN	Motorola
2N4919	Power PNP	Motorola
2N4939	Dual PNP	Motorola
1N821	TC Zener 6.2 V	Motorola
1N100	Ge diode	Sylvania
1N5394	Si Rectifier	Westinghouse
U1898E	N FET	Amelco/Teledyne
1N5312	Const Current Diode	Motorola
2N4401	Si NPN	Motorola
1000pF ½%	Mica Cap	General Inst./Miconics
2000pF ½%	Mica Cap	General Inst./Miconics
10000pF ½%	Mica Cap	General Inst./Miconics
31-223	Two Conductor BNC (Panel)	Amphenol
31-224	Two Conductor BNC (Cable)	Amphenol
33-101	BNC to Microdot Adapter	Amphenol
SE	Two pin BNC to coax Microdot Adapter	Unholtz-Dickie



* 5GΩ FOR -2

** 2.2µF/100V FOR K OPTION

FIG 5.3

TOLERANCES (EXCEPT AS NOTED)	UNHOLTZ-DICKIE CORP
DECIMAL	SCALE 2X; DRAWN BY TU; APPROVED BY
FRACTIONAL	TITLE COMPONENT LAYOUT CHARGE CONVERTER
ANGULAR	DATE 2/13/73; DRAWING NUMBER C 123.

D22PM, PM-2

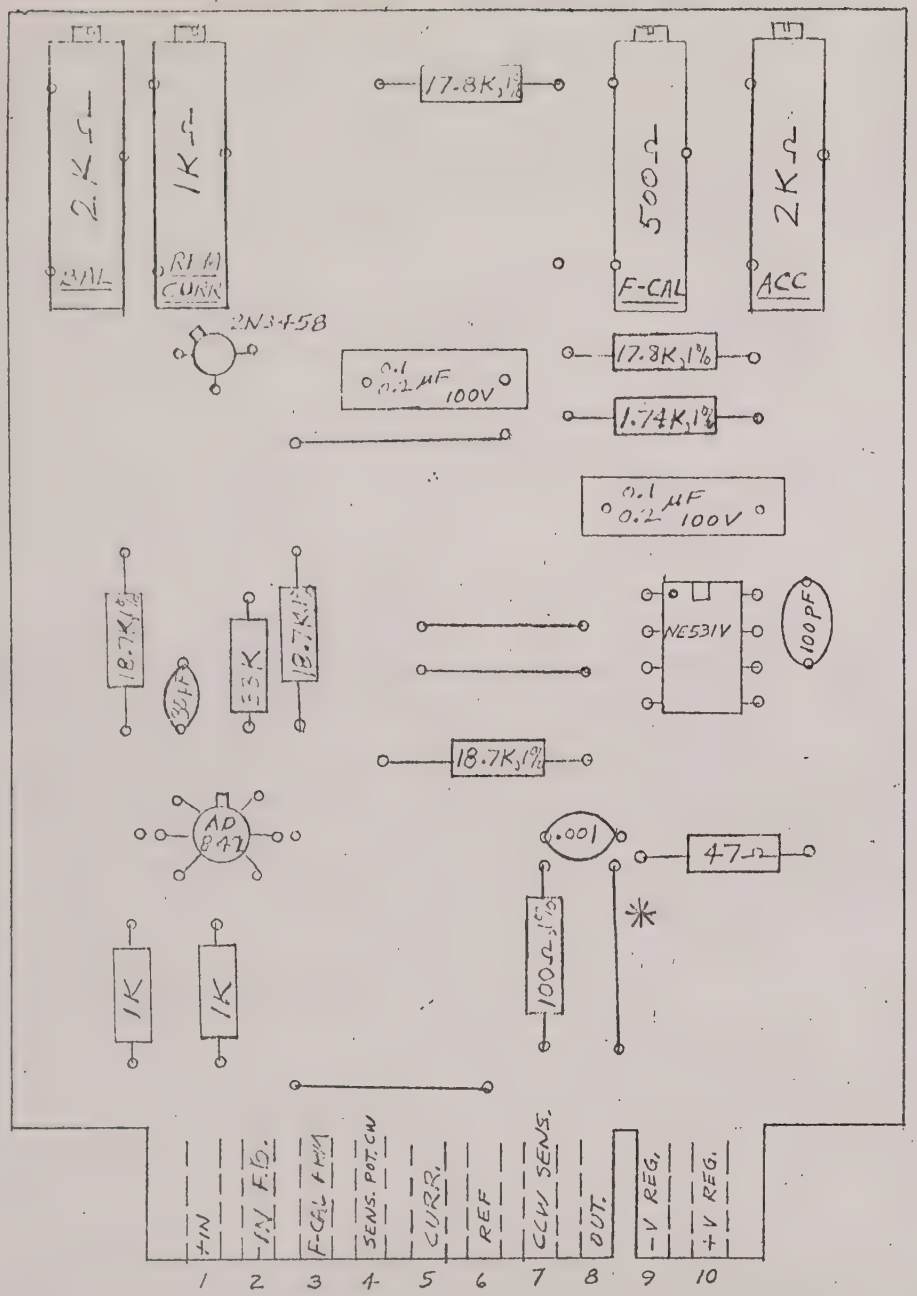
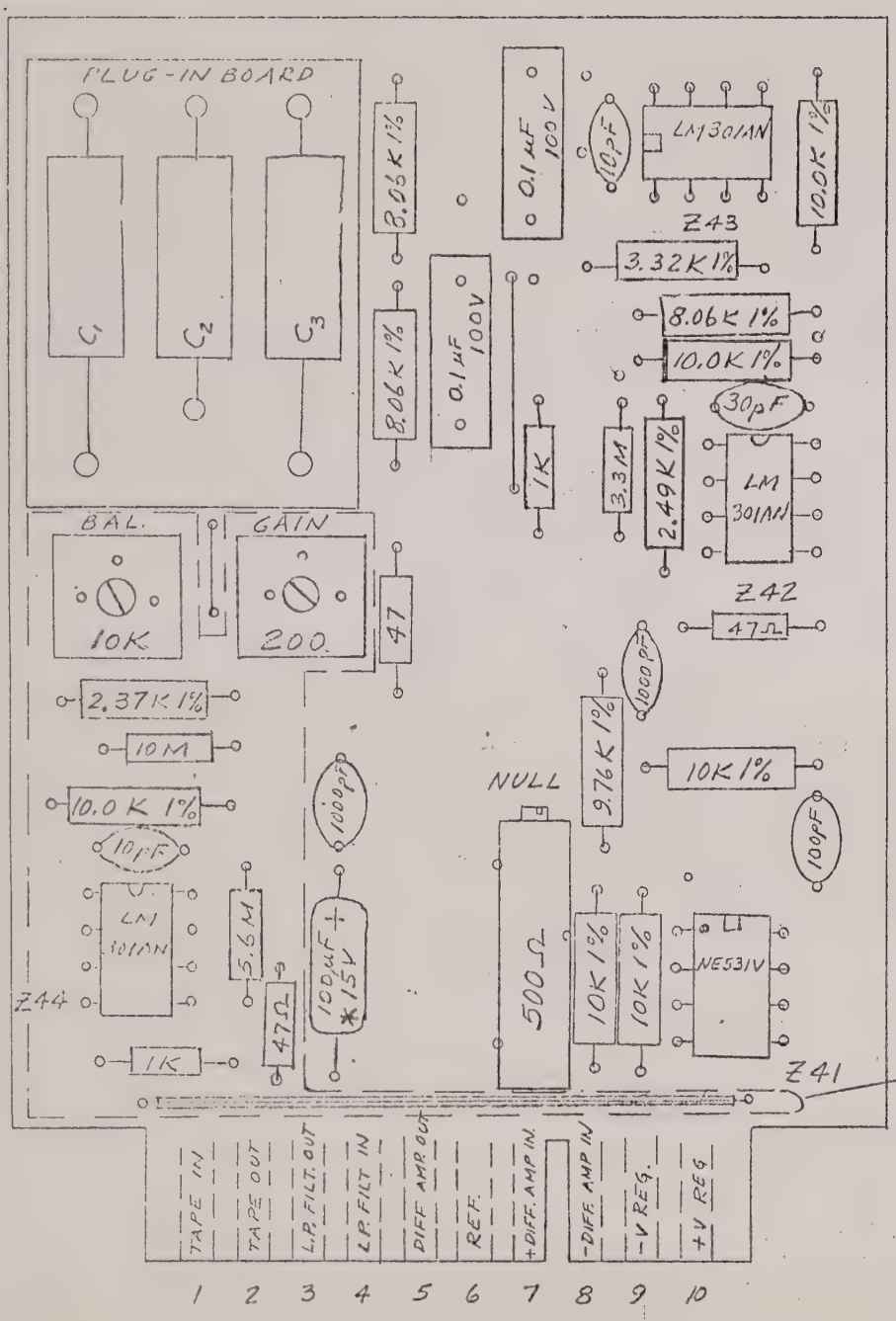


FIG 5.4

* JUMPER REPLACED BY 68/20V CAPACITOR FOR OPTION "T" FOR D22PMH

D22PM
D22PMH

TOLERANCES (EXCEPT AS NOTED)	UNHOLTZ-DICKIE CORP.
DECIMAL ±	SCALE — DRAWN BY TU — APPROVED BY
FRACTIONAL ±	TITLE DIAL-A-GAIN AMPLIFIER COMPONENT LAYOUT
ANGULAR ±	DATE 9-13-72 — DRAWING NUMBER A 12 519



	STD. 10kHz (±2% RESP)	5KHz
C_1	2000 pF ±2%	4000 pF
C_2	500 pF ±5%	1000 pF
C_3	1000 pF ±1%	2000 pF

NOTE : C_2 adjusted at factory

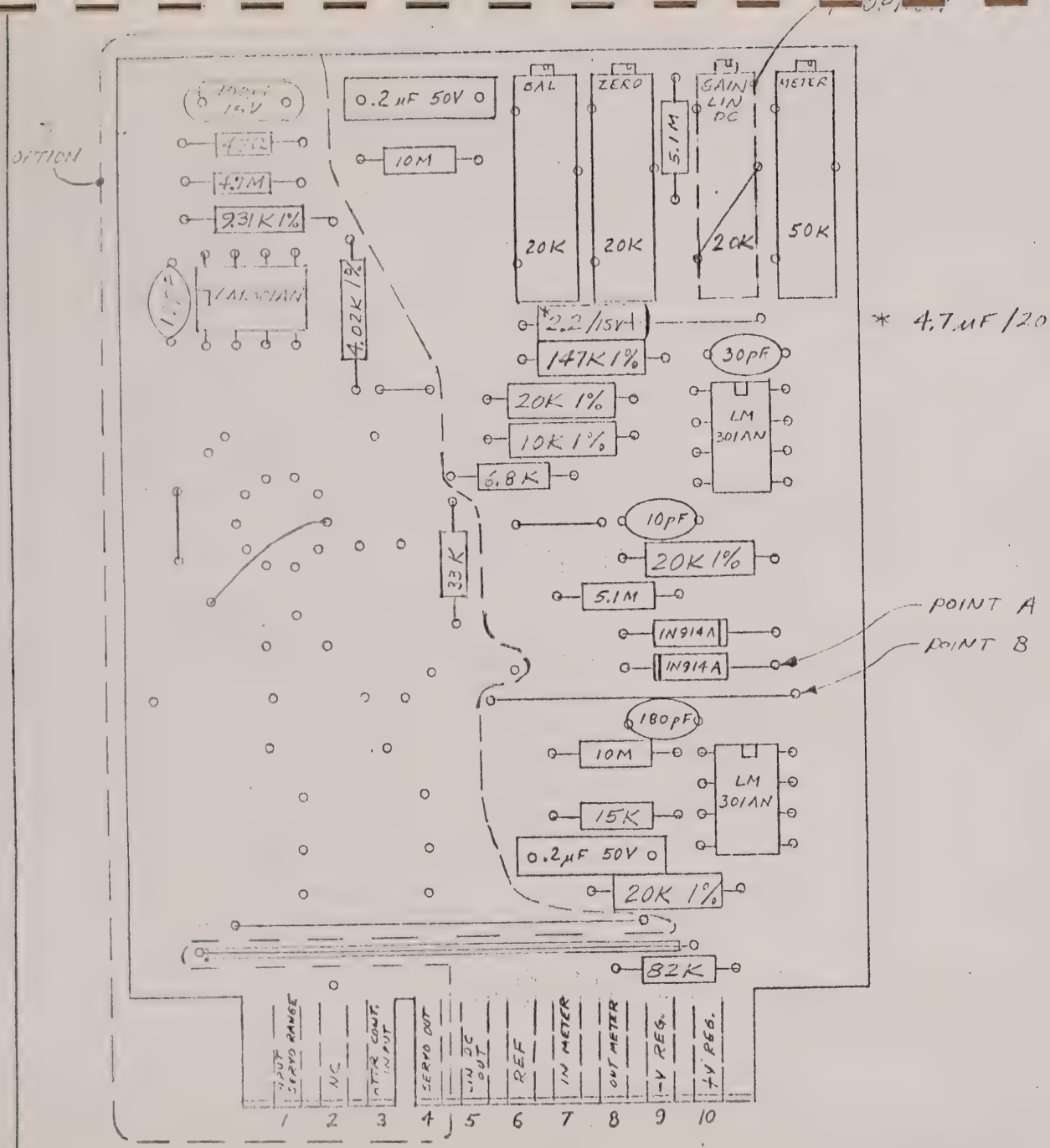
* 2ea 100 μF/15V FOR "-2" OPTION

DELETE WITH "C" OPTION

D22PMH; PMH-2
D22PM; PM-2

TOLERANCES (EXCEPT AS NOTED)	UNHOLTZ-DICKIE CORP
DECIMAL ±	SCALE 2X; DRAWN BY TU; APPROVED BY
FRACTIONAL ±	TITLE DIFF. AMP. - L.P. FILTER-TAPE COMPONENT LAYOUT
ANGULAR ±	DATE 9-19-72; DRAWING NUMBER C12312

FIG 5.5



* 4.7µF/20V FOR -2

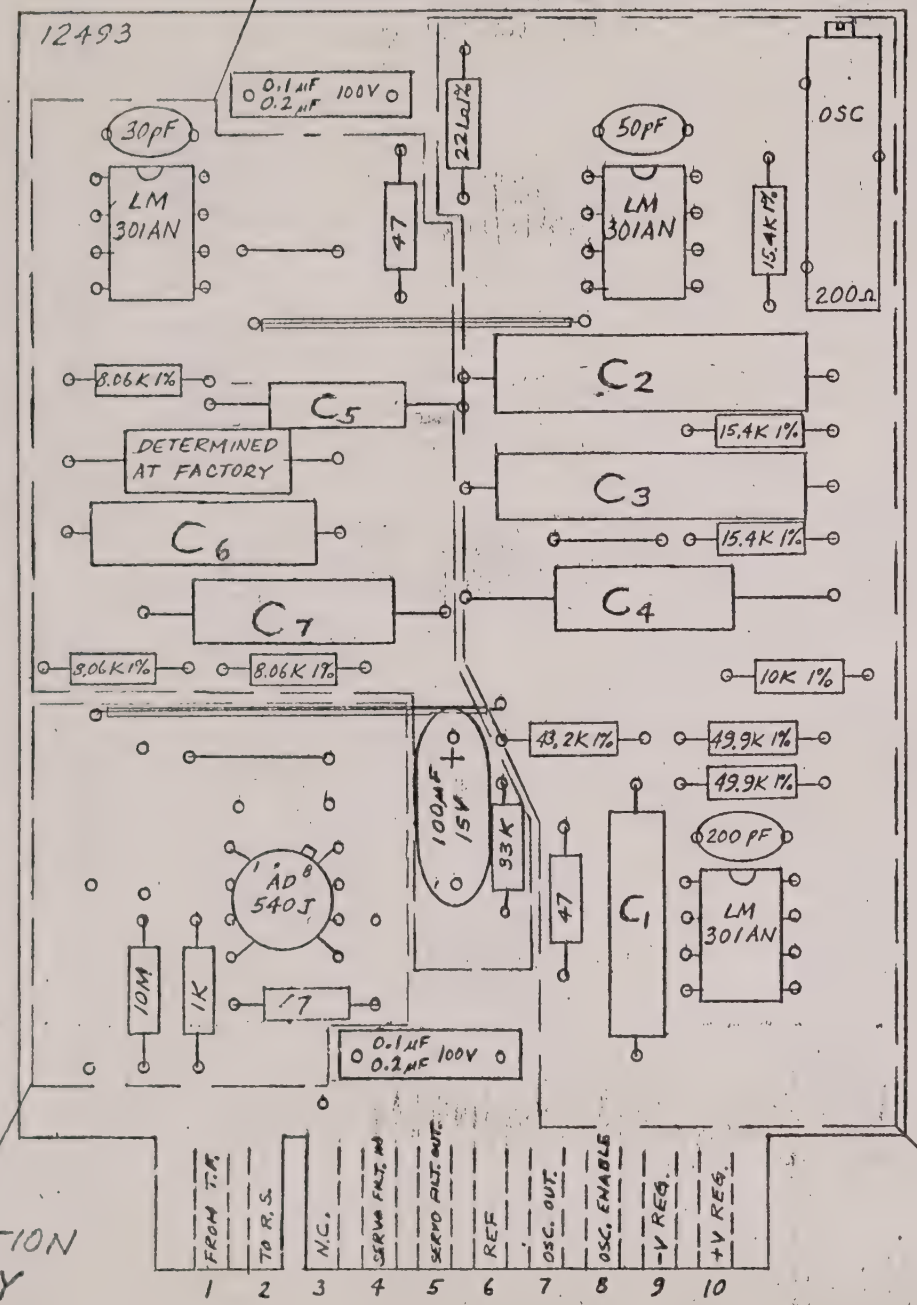
D22PM
D22PMH
S & F OPTIONS

UNIHOLTZ-DICKIE CORP

COMPONENT LAYOUT
METER-SERVO CARD

DATE 10-30-72

DRAWING NUMBER C12372

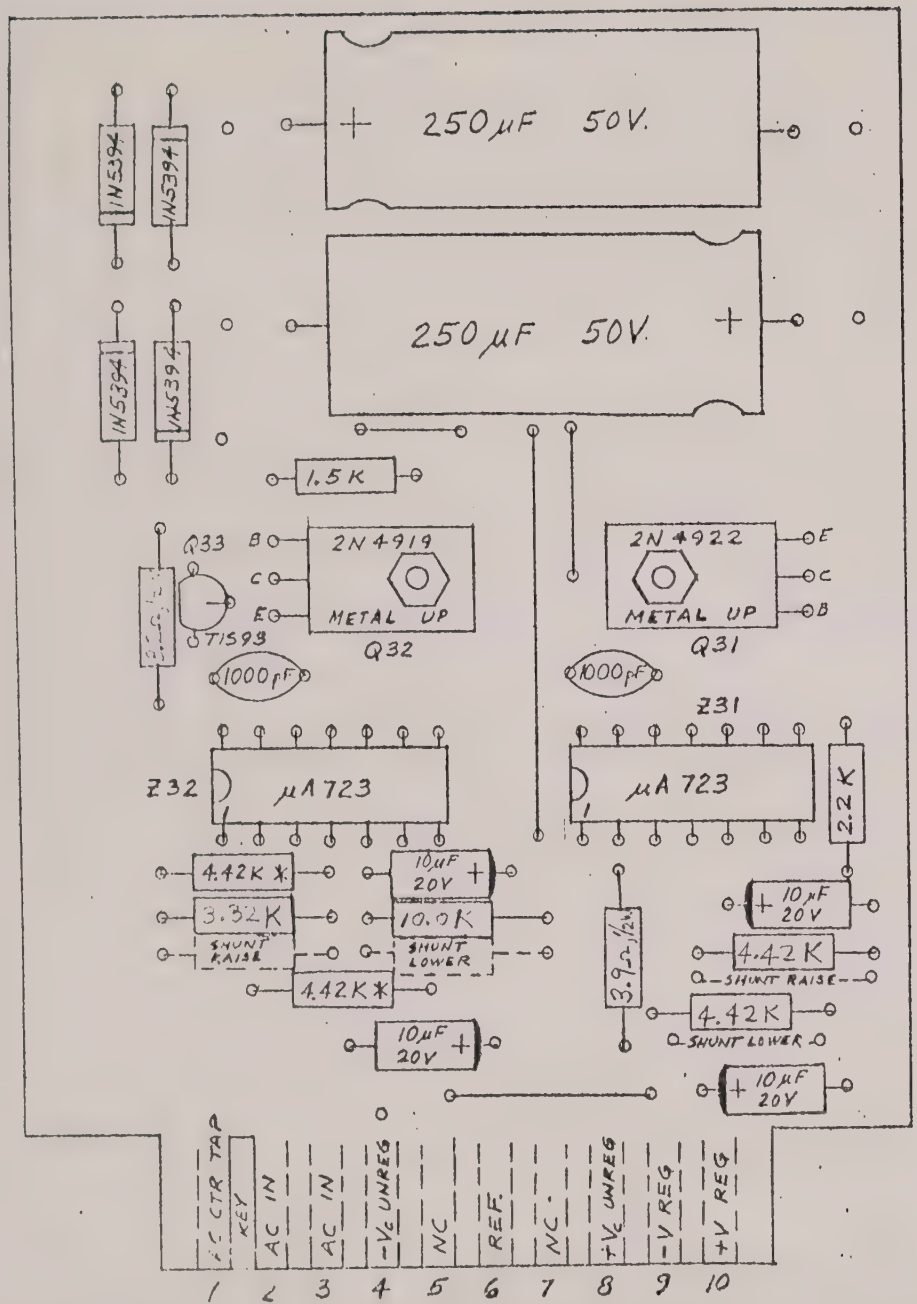


	2KHZ	5KHZ	10KHZ	4KHZ	3KHZ
C_5	.001	390pF	200pF	500pF	680pF
C_6 *	.015	.005	.0033	.0068	.01
C_7	.0068	.0027	.0012	.0033	.0047

* ADJUSTED AT FACTORY

	100HZ	150HZ	200HZ
C_1	.1	.068	.047
C_2	1.0	.68	.47
C_3 *	.47	.33	.22
C_4	.015	.01	.0068

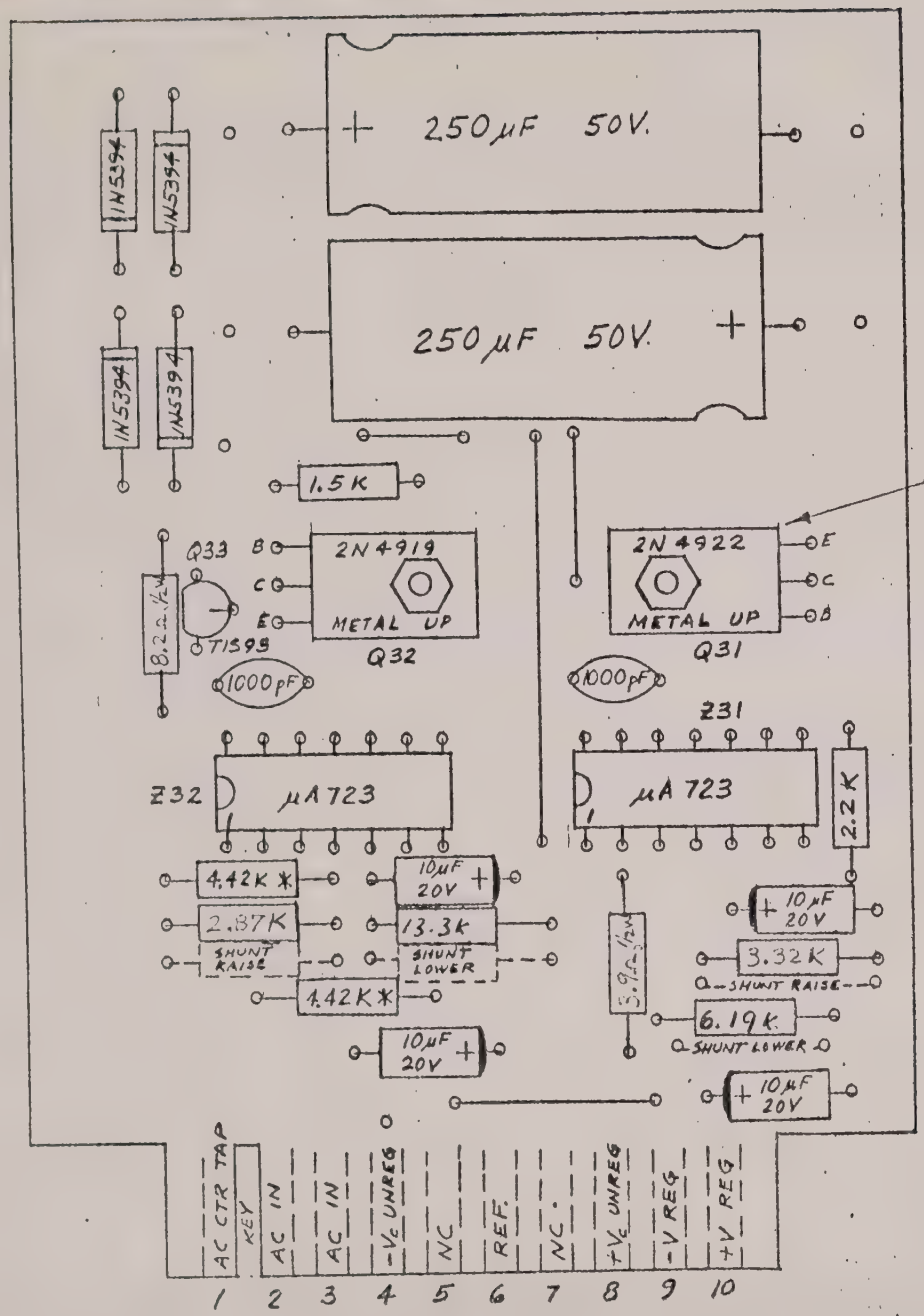
TOLERANCES (EXCEPT AS NOTED)	UNHOLTZ - DICKIE CORP.
DECIMAL	SCALE — DRAWN BY TU — APPROVED BY
FRACTIONAL	TITLE COMPONENT LAYOUT OSC - TF BUFFER - SERVO FILTER
ANGULAR	DATE — DRAWING NUMBER



OUTPUT POWER SUPPLY

D22 SERIES

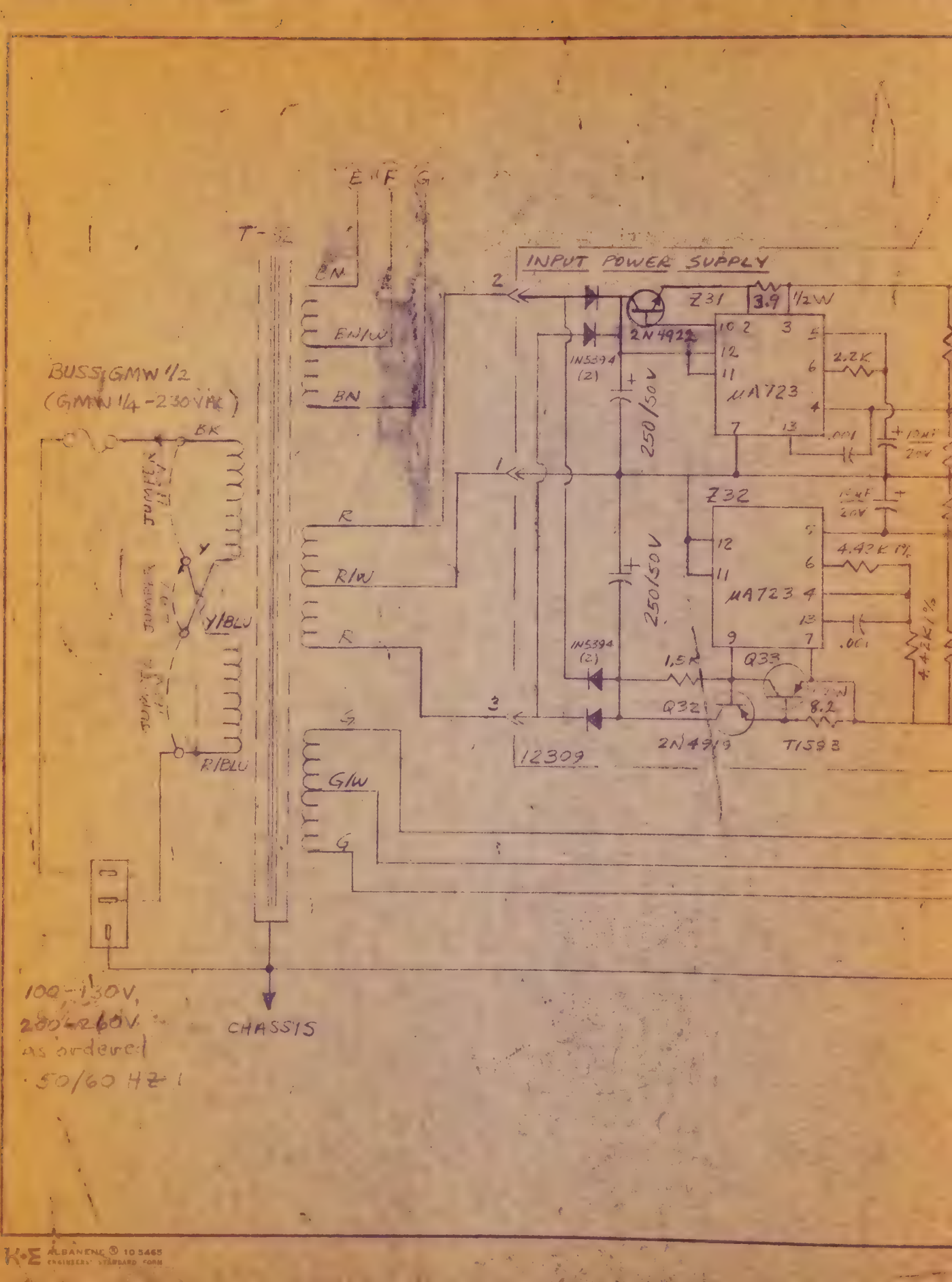
TOLERANCES UNLESS NOTED	UNHOLTZ-DICKIE CORP
DECIMAL ±	±15V
SCALE	
DRAWN BY TU	
FRACTIONAL ±	TITLE COMPONENT LAYOUT DUAL REG. POWER SUPPLY
ANGULAR ±	DATE 10-4-74
DRAWING NUMBER C12310	



INPUT POWER SUPPLY

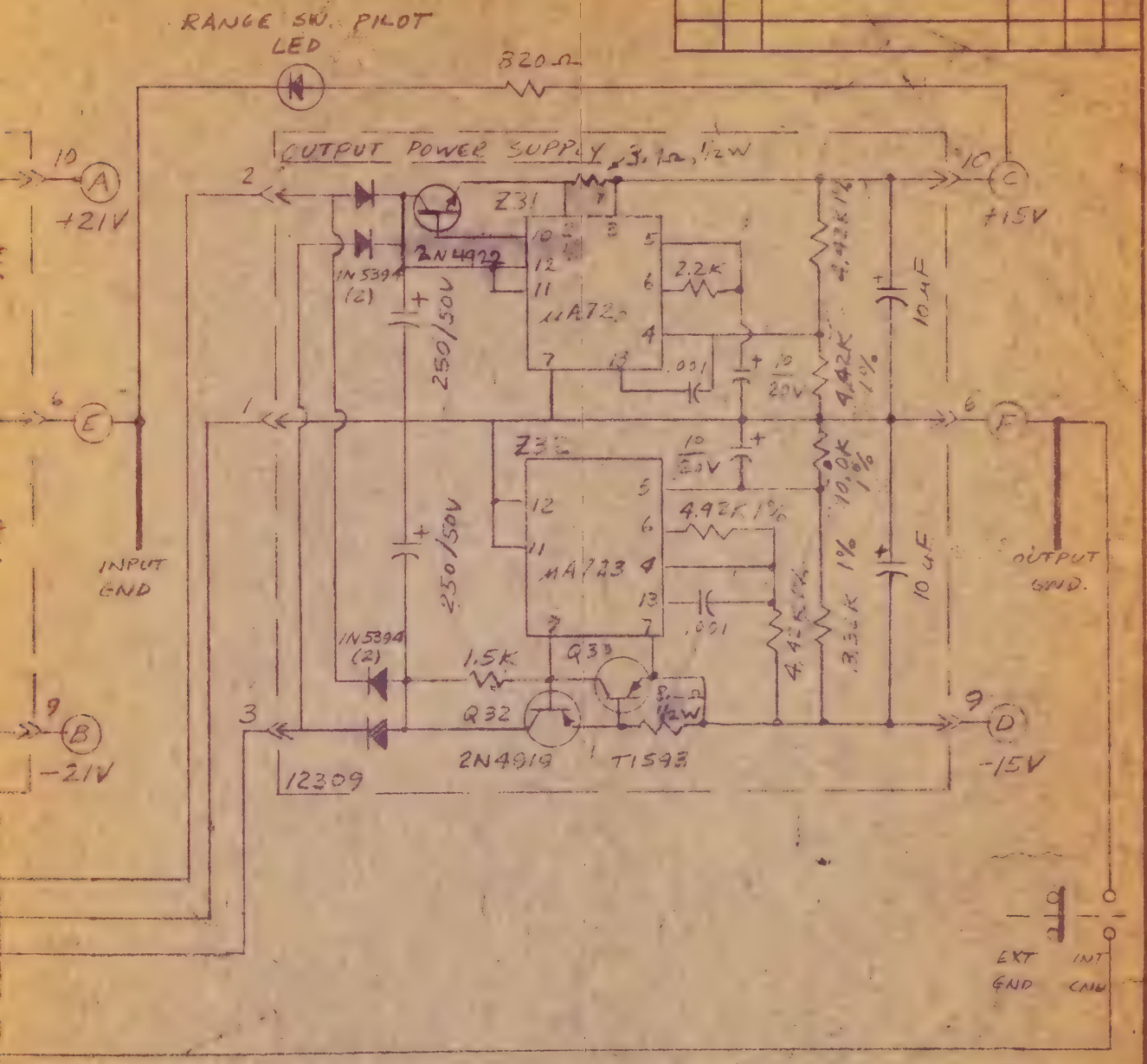
D22PM
D22PMH
D22PMR

TOLERANCES (EXCEPT AS NOTED)	UNHOLTZ-DICKIE CORP		
DECIMAL ±	±21V	SCALE	DRAWN BY TU / APPROVED BY
FRACTIONAL ±	TITLE COMPONENT LAYOUT DUAL REG. POWER SUPPLY		
ANGULAR ±	DATE 10-4-74	DRAWING NUMBER C12310	



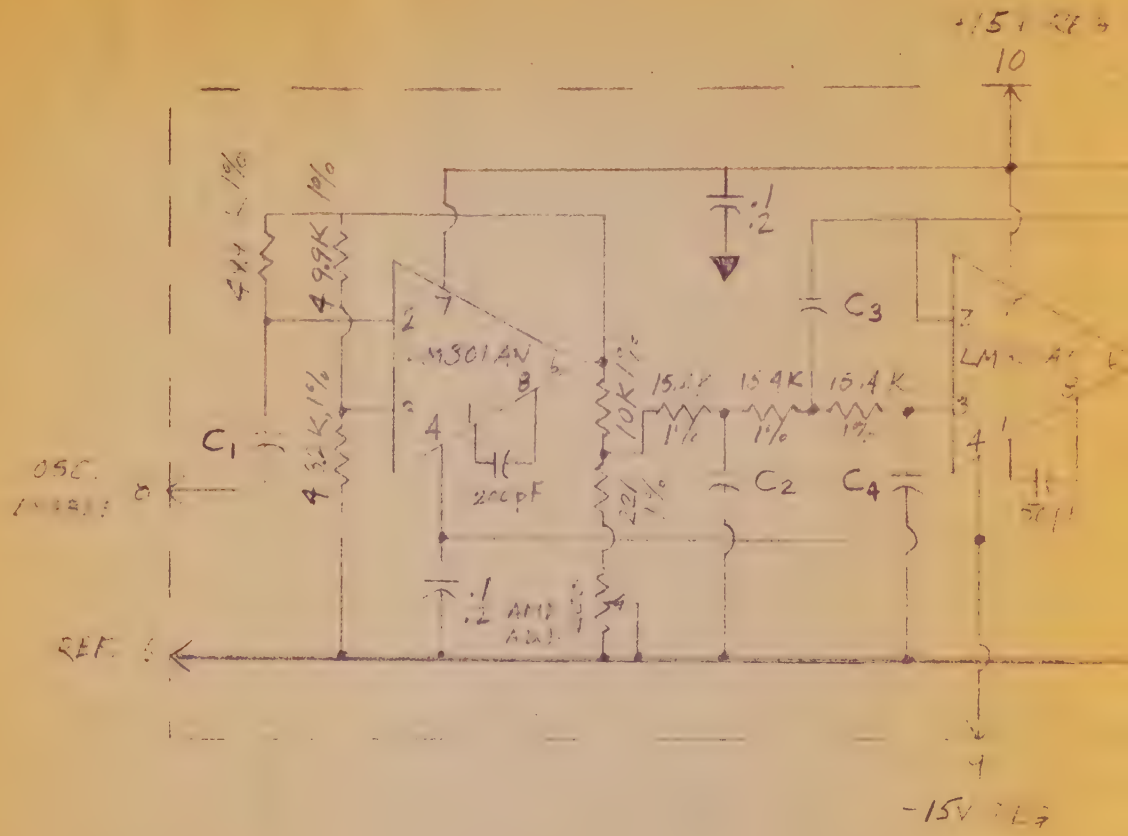
K·E ALBANENE ® 10 5465 ENGINEERS' STANDARD FORM

DATE	SYM	REVISION RECORD	ALTH.	DR.	CK
6/73	A	20V → 21V	TV		
	B				
	C				



TOLERANCES (EXCEPT AS NOTED)	UNHOLTZ-DICKIE CORP.		
DECIMAL ±		SCALE —	DRAWN BY TV APPROVED BY
FRACTIONAL ±	TITLE POWER SUPPLY CIRCUIT SCHEMATIC		
ANGULAR ±	DATE 12-10-12	DRAWING NUMBER B12362	

MADE IN U.S.A.

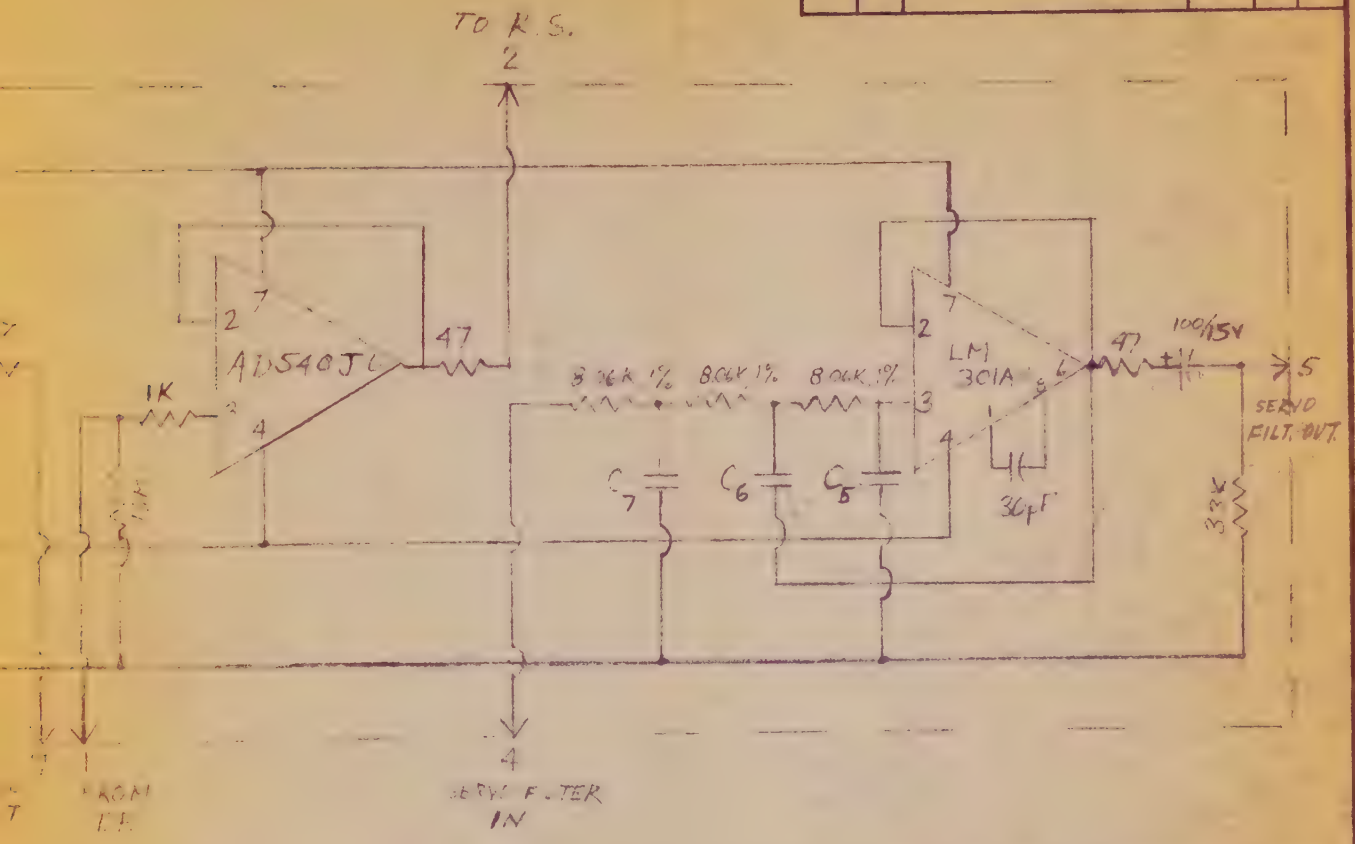


* ADJUST

	100HZ	150.1Z	200Hz	1KHZ
C_1	.1	.062	.047	.01
C_2	1.0	.68	.47	.1
C_3*	.47	.33	.22	.047
C_4	.015	.01	.0068	.0015

CRYSTALONICS 10 9406
ENGINEERS STANDARD FORM

DATE	SYM	REVISION RECORD	AUTH.	DR.	CK.
4/75	A	ECO REV	TG		



AT FACTORY

	2KHz	5KHz	10KHz	3KHz	4KHz
C_5	.001	390pF	200pF	680pF	500pF
C_6	.015	.005	.0033	.01	.0068
C_7	.0068	.0027	.001	.0047	.0033

TOLERANCES (EXCEPT AS NOTED)			
DECIMAL ±		SCALE	DRAWN BY JD APPROVED BY
FRACTIONAL ±	TITLE CIRCUIT SCHEMATIC OSC. – TG BUFFER – SERVO FILTER		
ANGULAR ±	DATE 9-5-74	DRAWING NUMBER B12522	

MADE IN U.S.A.

A SURVEY OF PRESENT GENERATION SHOCK AND VIBRATION SIGNAL CONDITIONERS

By: Theron Usher, Jr., Unholtz-Dickie Corporation, Hamden, Connecticut

Dr. Usher is presently engaged in signal conditioner development at Unholtz-Dickie Corp. He received the D. Eng. degree at Yale University in 1957 and subsequently has been engaged in university teaching, consulting in the field of underwater signal processing, and in research and development activities for a wide range of projects in the field of vibration testing and measurement. His published work includes a number of technical articles in the above fields. He is a former associate editor for the ASA, and is currently a member of IEEE, IES, and Sigma Xi.

INTRODUCTION

The fields of digital computer technology and signal-processing techniques have experienced a period of explosive growth durthe past decade. The development of analog signal conditioning equipment during the same period has not been nearly so dramatic, but some recent developments, as well as extensions and improvements of older ideas, deserve discussion.

The following areas are covered in this paper:

(1) Mulitpurpose signal conditioners for a variety of input transducers.

(2) Differential charge amplifiers and applications with high-temperature accelerometers.

(3) Automatic range control and remote range control.

(4) Low-frequency, low-amplitude measurements.

(5) Direct-coupled differential amplifiers and bridge conditioners.

The above topics, which are by no means exhaustive, are discussed from the standpoints of application areas, important features, and typical specifications. However, before this discussion is undertaken, typical features of most signal conditioners, and charge amplifiers in particular, are reviewed in the following section. This discussion for many readers will be largely tutorial.

1. TYPICAL FEATURES

General Design

Early multichannel signal conditioners used common power supplies, but modular instrumentation with individual power supplies now constitutes a great majority of acquisitions. Six or more modules fit in a rack adapter for system applications, but single units can also be used for portable laboratory measurements. Power transformers are usually electrically shielded.

Current instrument design utilizes balanced regulated power supplies with short-circuit protection and balanced circuit design employing integrated circuit operational amplifiers wherever possible. This is generally true even for AC coupled designs, because balanced circuit design decouples any possible power supply effects from the signal bus to a high degree, and thus prevents undesirable feedback effects through the power supplies. The balanced circuit design also minimizes switching transients and allows the overall circuit to have a minimum number of coupling capacitors, which reduces the cost of the instrument.

The charge amplifier has evolved to be the conditioner of choice for piezoelectric accelerometers and other capacitive transducers. The primary reason for this is that the overall conversion gain of the transducer-charge amplifier combination is virtually insensitive to the length of the cable between the transducer and conditioner. This is not the case when a voltage amplifier is the signal conditioner, since the overall gain becomes dependent on the loading capacitance of the interconnecting cable.

Low noise, wide frequency range and high slew rate are desirable features of all signal conditioners. For the charge amplifier, high input charge capacity without saturating the input charge converter is also highly desirable.

Noise

Noise specifications are generally given in terms of a component referred to the input plus a component referred to the output so that the conditioner can be evaluated for any gain condition. For the charge amplifier a representative specification might read:

> .005 pC (picocoulombs) rms plus .0015 pC rms/1000 pF input capacitance RTI (referred to input) plus 1 mV rms RTO for a 2 Hz to 20 kHz bandwidth.

The detailed RTI specification is necessary because the equivalent input noise of the charge amplifier increases with transducer capacitance as well as cable capacitance. The signal detectability may easily be calculated once the noise specification is known. For instance, with an accelerometer having a sensitivity of 80 pC/g, and a capacitance of 1000 pF (Unholtz-Dickie Model 75D21) with a 30 foot cable (1000pF) the wideband acceleration noise RTI due to the charge amplifier is:

$$g_n = \frac{.005 + 2(.0015)pC}{80\ (pC/g)} = 10^{-4}\ g\ rms$$

Thus 10^{-3} g can easily be measured with a signal-to-noise ratio fo 20 dB.

Wideband Characteristics

Wide frequency range implies uniform frequency response over the range but does not necessarily assure full output can be maintained over that range. The amplifier output should be able to slew fast enough to reproduce large high-frequency transients. Typical frequency response specifications are:

±5% 2 Hz to 30 kHz, ±1% 10Hz to 10 kHz

The charge amplifier output should generally be capable of providing 10V peak at 20 kHz which corresponds to an output slew rate of 1.25 V/μsec since:

$$\text{Slew Rate} = 2\pi\ f_{upper}\ V_{peak} \times 10^{-6}\ V/\mu sec$$

The maximum input charge for a charge amplifier is determined by the characteristics of the input charge converter. A typical charge converter has a 1 mV/pC transfer ratio and 10 V peak output without saturating. Thus a charge of 10^4 pC may be handled at the input without saturating the input converter. Saturating the input converter can cause loss of signal due to long recovery time. For an accelerometer having a sensitivity of 10 pC/g, this corresponds to a peak acceleration of 1000 g. A typical slew rate for a charge converter is 6 V/μsec (10 V output at 100 kHz). For reference a simplified block diagram for a charge amplifier is shown in Fig. 1.

Transducer Sensitivity Noramlization

It is desirable to have the rated value of the ranged output of a signal conditioner represent the same full-scale physical input values regardless of the transducer sensitivity or transfer ratio. A necessary feature to accomplish this is the gain-normalizing amplifier in Fig. 1. The gain normalization function is usually accomplished by a multi-turn precision potentiometer which adjusts the feedback ratio of the gain-normalizing amplifier. The transducer sensitivity is set directly on the turns-reading dial of the potentiometer, which automatically provides a signal conditioner gain which is inversely related to the transducer sensitivity.

A typical charge amplifier is designed to accept transducer sensitivities from 1 pC/g to 100 pC/g in two 10:1 ranges. The significant digits of the sensitivity are set on a ten-turn locking dial. Rated output is typically provided for full scale inputs from 1g to 1000g, although extension of this range by 10:1 at either end is not uncommon.

Ground Signal Rejection

In many cases a ground loop can exist because the transducer case is attached directly to the metallic test structure and the test structure is connected electrically to the reference bus of the instrumentation. Refer to Fig. 2. In many cases there is a significant voltage which exists across this electrical connection because of long length, magnetic fields, and ground return currents. The resulting current through the shield of the transducer cable establishes an undesirable signal voltage, which is fed to the input converter through the capacitance of the cable and transducer. This input is amplified by the signal conditioner to produce a large undesirable output.

A simple remedy is, of course, to insulate the transducer case from the structure, but this may not be physically desirable or possible. An alternate solution which allows the direct connection of the transducer to the structure can be had by separating the reference for the input amplifiers and output amplifiers at "X" in Fig. 2 and feeding the signal on the input reference bus to a differential connection on the output amplifiers. This interrupts current I and prevents the ground signal voltage V from feed-

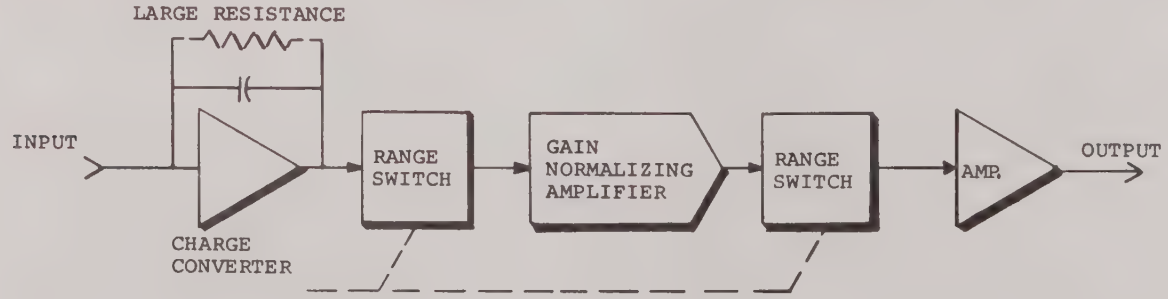


FIG. 1 SIMPLIFIED BLOCK DIAGRAM FOR CHARGE AMPLIFIER

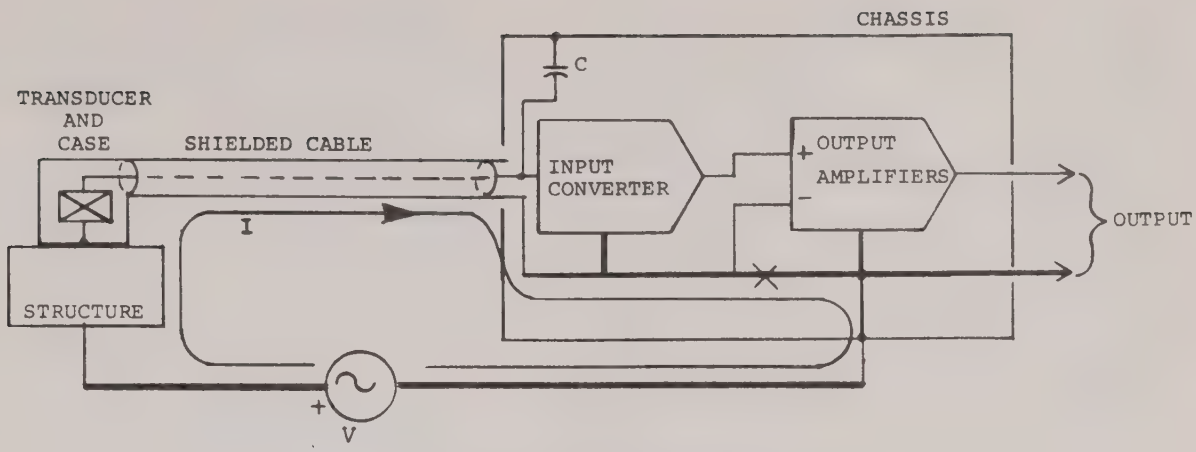


FIG. 2 EQUIVALENT CIRCUIT WITH TRANSDUCER GROUNDED AT TEST STRUCTURE

ing through the cable capacitance. Care must be taken in guarding the input converter so that the capacitance C from chassis to input is minimized. Rejection of the input ground signal for charge amplifiers is typically better than 50-60 dB.

A two-position switch is usually provided in most single-ended conditioners to accommodate either isolated or grounded transducer cases.

Remote Preamplifiers

Excessively long cables from the transducer have several disadvantages:

(1) The signal-to-noise ratio decreases with length (note the noise specification for charge amplifiers).

(2) For capacitive transducers, triboelectric noise can be a problem, even with treated cables.

(3) Low-noise cables are comparatively expensive, and some commonly-used varieties are not particularly resistant to abuse.

A remote preamplifier, used instead of the internal charge converter, removes most of these objections because it can be located close to the transducer. The cable between the preamplifier and the conditioner can then be an inexpensive, sturdy coaxial variety in which the center conductor not only carries the signal voltage but also the operating voltage and current for the preamplifier. Triboelectric noise is not a problem because of the low source impedance of the output of the remote preamplifier.

Provision for using either the internal converter or a remote preamplifier by means of a switch has been a desirable feature for signal conditioners. The preamplifier power supply is included in the signal conditioner.

Miscellaneous Features

Many signal conditioners provide for a variety of low-pass filters, since there may be no need to measure over the entire frequency band of the conditioner, and maximum signal-to-noise ratio is desired. High-pass filtering is discussed in a later section.

Some means for providing full-scale output calibration and a test of the cable and transducer integrity is often provided.

Optional features on signal conditioners can also include:

(1) Constant sensitivity output (i.e. 10 mV/g) for control of vibration tests.

(2) High-current drivers for galvanometer recording and driving long lines,

(3) Meter indication,

(4) Logarithmic (DC) conversion of the output for plotting purposes.

2. MULTIPURPOSE SIGNAL CONDITIONERS

Several years ago facilities which had cause to work with a large variety of transducers, such as piezoelectric accelerometers, servo accelerometers, piezoresistive accelerometers, strain gages, thermocouples, etc., required several different instruments to accommodate the measurement tasks. This proved to be expensive, especially if the individual utilization time of the separate instrument happened to be low. The solutions to this problem which have evolved are based on the observation that some portion of the electronics for the different instruments is quite similar.

One solution has been to provide and instrument main frame with the necessary power supplies, input connectors and output connectors. Plug-in cards with attached front panels and supplementary controls provide the condition-

ing requirements for each separate application, and include a charge amplifier, a bridge conditioner with amplification, a carrier amplifier and other bridge conditioners.

Another recent solution has been to provide an instrument main frame with the necessary power supplies, direct-coupled post-amplifier, meter, gain controls, input connectors and output connectors. Separate plug-in chassis provide the necessary conditioning for capacitive transducers (charge converter), servo accelerometers, and bridges with 1, 2, or 4 active arms. The separate plug-in chassis also contain front panel controls for gain normalization and calibration.

A third solution, which differs somewhat from the so-called "Universal Signal Conditioners" described above, provides a single instrument (U-D Model D22PMR), shown in Fig. 3, with front-panel switching for the following applications:

(1) Charge amplifier for piezoelectric accelerometers, force gages, and pressure transducers.

(2) High input-impedance voltage amplifier for general applications.

(3) Direct inputs from single strain gages for dynamic strain measurement.

(4) Inputs from remote preamplifiers.

All four applications above are provided by changing connections to the input converter or by rerouting the signal past the input converter (application 4). In addition, the strain-gage mode of operation provides the selection of several accurately-determined values of constant-current excitation for the strain-gage. The current is applied through the center conductor of the connecting cable.

FIG. 3 MODEL D22PMR
MULTIPURPOSE SIGNAL CONDITIONER

The feature of sensitivity normalization is preserved for all modes of operation. The explanation of how this is accomplished for the strain-gage mode follows. The gage factor F is defined by:

$$F = (\Delta R/R)/(\Delta L/L) \qquad (1)$$

where $\Delta L/L$ is strain and ΔR is the change of resistance for gage resistance R. The change in output voltage for the gage with constant current excitation is

$$\Delta V = \Delta RI \qquad (2)$$

The gage transfer ratio or sensitivity S is defined by

$$S = \Delta V/(\Delta L/L) \qquad (3)$$

Substituting (1) and (2) in (3) yields

$$S = FRI \quad \text{millivolts/millistrain} \qquad (4)$$
$$\text{or mV/1000 microstrain}$$

Since F and R are accurately determined by the gage manufacturer and I is accurately (±1%) determined by a switch setting on the conditioner, a sensitivity is easily calculated and set on the gain-normalization dial.

For example, if F = 2.00, R = 120 ohms, and I = 40 ma, we have S = (2)(120)(.040) or 9.60 mV/1000με.

Transducer sensitivities from 1 to 100 mV/engineering unit can be accommodated. (Here one engineering unit(eu) is 1000 με, 1 g, 1 psi, etc.) Ranging is provided for full-scale inputs from 1 to 1000 eu for the charge or voltage mode, and from 10 to 10000 με in the strain-gage mode. Noise in the strain-gage mode is typically less than 0.5 με rms RTI for the numerical example above.

A multivibrator can also be activated to dynamically shunt a preselected resistance value across the strain gage. The peak-to-peak value of the simulated square wave strain can easily be calculated and used as a check on the calibration of the instrument.

The third multipurpose signal-conditioner described above does not provide the exceptionally wide application range that the "Universal Signal Conditioners" provide, particularly for bridge measurements, but it does provide a means for making the most commonly used dynamic measurements. Also, only one instrument is required rather than one main frame and several plug-in panels.

3. DIFFERENTIAL CHARGE AMPLIFIERS

High-Temperature Measurement

Applications for monitoring vibrations of such sources as jet engines, nuclear power plant components, and automobile mufflers have required high-temperature accelerometers. Accelerometers have been developed for measurements at temperatures as high as 1400°F, but the shunt resistance of such accelerometers decreases to the vicinity of

10 kilohms at this temperature. Typically, the shunt resistance of high-temperature accelerometers decreases by a factor of 5-10 for a 200°F increase in temperature above temperatures of 700°F.

Some high-temperature accelerometers have also been constructed so that the crystal is isolated from the case, whereas the conventional lower-temperature accelerometer is constructed with one side of the crystal common to the case. The isolated construction requires a balanced two-wire signal connection with the shield preferably connected to the case. The balanced configuration is apparently an outgrowth of the situation that electrostatic shielding is often not very good in certain areas for high-temperature vibration-monitoring applications. The balanced line offers the best possibility for power frequency harmonic rejection.

High-temperature accelerometers have thus caused the following design changes and emphases in charge amplifiers:

(1) The input charge converters have been redesigned so that they will not saturate or block due to low resistances across the input.

(2) The noise due to the input charge converter at low frequencies must be extremely low, since this noise is emphasized by decreasing input shunt resistance.

(3) High-pass filters have been added to charge amplifiers to sharply cut off the spectrum below the minimum signal frequency to maximize the signal-to-noise ratio.

(4) Differential charge converters have been designed to accommodate the isolated-crystal accelerometers.

Noise Characteristics

The relative noise spectrum (RTI) for a differential charge amplifier with a very large value of shunt resistance is shown in Curve A of Fig. 4. Note that the spectrum rises slightly at low frequencies, which is characteristic of the high-quality FET selected for the input device in the charge converter.

When a relatively low value of shunt resistance (50 kilohms) is placed across the input of the charge converter, the closed-loop forward gain of the device is not markedly affected, but the loop-gain of the charge converter is markedly decreased at the lower frequencies due to the low value of R_s. The effect is to cause the noise spectrum to increase at 1/f rate above curve (A) as frequency decreases. The frequency at which the spectrum begins to deviate from curve (A) is determined by:

$$f_c = 1/(2\pi R_s C_f) \qquad (5)$$

Where R_s is the shunt resistance and C_f is the feedback capacitance of the charge converter. For R_s = 50 KΩ C_f = 1000 pF, f_c = 3180 Hz. Curve (B) in Fig. 4 shows the effect described.

Curve (B) also shows the effect of a three-pole Butterworth high-pass filter (-3 dB at 10 Hz) placed after the charge converter. The decrease in effective noise RTI below 10 Hz is due to this filter. Numerical integration of the square of Curves (A) and (B) from 1 Hz to 20 kHz reveals that the rms value of the wideband noise for Curve (B) is approximately 10 times that for curve (A).

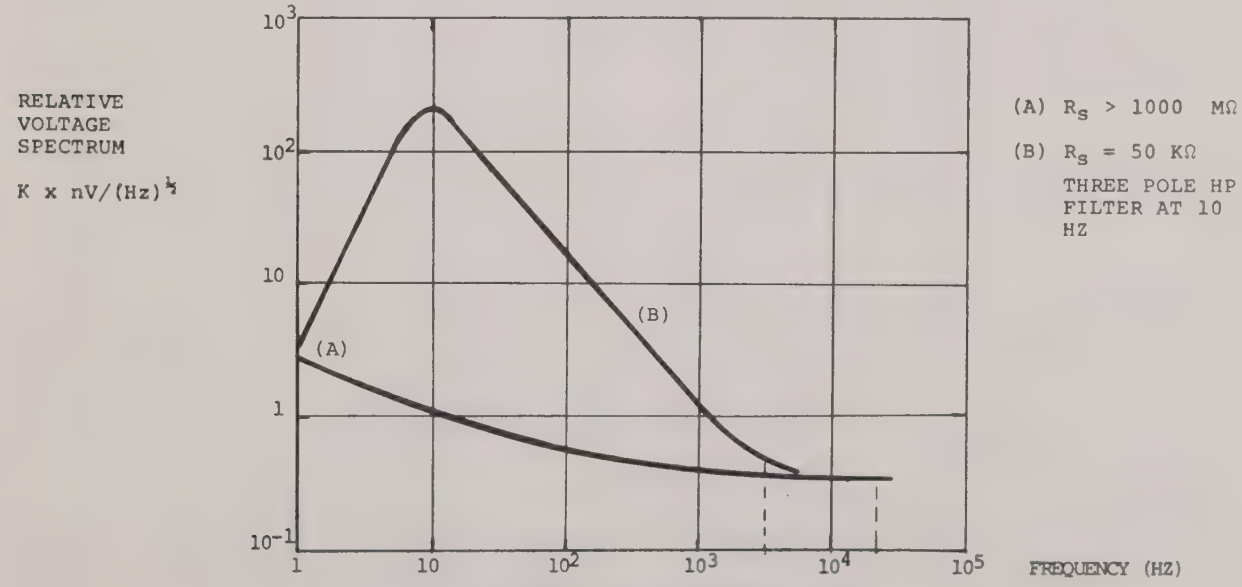


FIG. 4 RELATIVE NOISE SPECTRA FOR CHARGE CONVERTER WITH SHUNT RESISTANCE

A typical specification for the noise under the conditions for curve (B) is a maximum of .05 pC rms (U-D Model D22PMH). If the cut-off frequency for the high-pass filter can be increased for any reason, the low-frequency noise that is seen under conditions of low shunt resistance can be decreased. It is interesting to note that shunt capacitance at the input to the charge converter also increases the noise (RTI) of the charge converter, but in this case the spectral level is increased uniformly at all frequencies.

Differential Charge Converter

The differential charge converter is schematically shown in Fig. 5, along with other input parameters. It can be shown that the output voltage V_o is:

$$V_o = -\frac{Q}{C_f} + \frac{V_2C_2(C_1+C_3+C_f)-V_1C_1(C_2+C_4+C_f)}{C_f(C_1+C_2+C_3+C_4+2C_f)} \quad (6)$$

In Eq. 6 the first term represents the desired output from the accelerometer and the second and third terms represent the undesirable outputs from the power frequency (hum) sources V_1 and V_2. The capacitances C_1 and C_2 represent stray pickup capacitances for the power frequency voltages and C_3 and C_4 represent line-to-shield capacitances.

The signal-frequency gain of the charge converter is not dependent on the relative values of C_3 and C_4 if the gain of the differential amplifier is very high. However, the ability of the charge converter to reject power frequency signals due to the pickup through the stray capacitances C_1 and C_2 is critically dependent upon the external circuit parameters. In general, the second and third terms of Eq. (6) come close to cancelling each other only if the lines are well-balanced ($C_3 \simeq C_4$), the stray capacitances are very nearly equal ($C_1 \simeq C_2$) and the hum sources are equal or are the same source ($V_1 \simeq V_2$). The analysis leading to Eq. (6) is based on the assumption that the differential amplifier in Fig. 5 itself has perfect common mode rejection.

FIG. 6 MODEL D22PMH
DIFFERENTIAL CHARGE AMPLIFIER

Fig. 6 shows the front panel for the U-D Model D22PMH with front panel switches to control high and low-pass filtering, case isolation or grounding, and differential or single-ended charge conversion.

4. AUTOMATIC AND REMOTE RANGE CONTROL

The development of new aircraft, spacecraft and other large structures has required large instrument arrays for simultaneously monitoring motions and stresses on all parts of the test structure. Manual control of large instrument arrays is an almost impossible task for such situations.

Instruments have been developed for which the functions of full scale ranging, calibration, and transducer sensitivity normalization are completely controlled by digital means. However, it is the feeling of this author that such instruments require a large number of control lines and are wasteful of computer memory. Their utility as single-channel portable monitors is also questionable.

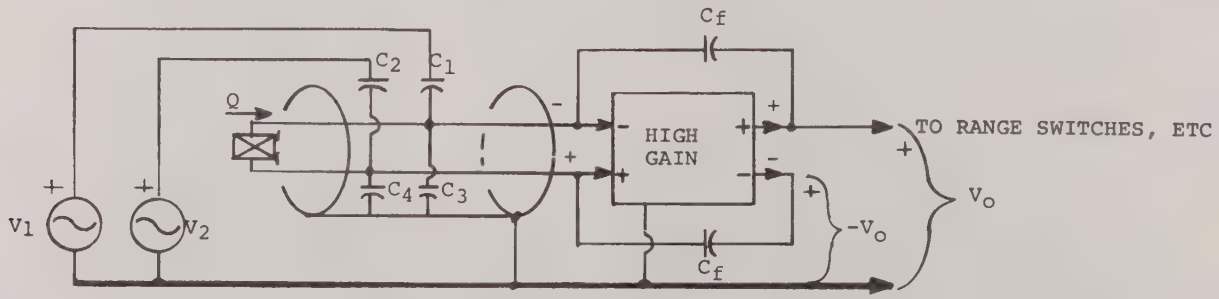


FIG. 5 EQUIVALENT CIRCUIT FOR
DIFFERENTIAL CHARGE CONVERTER

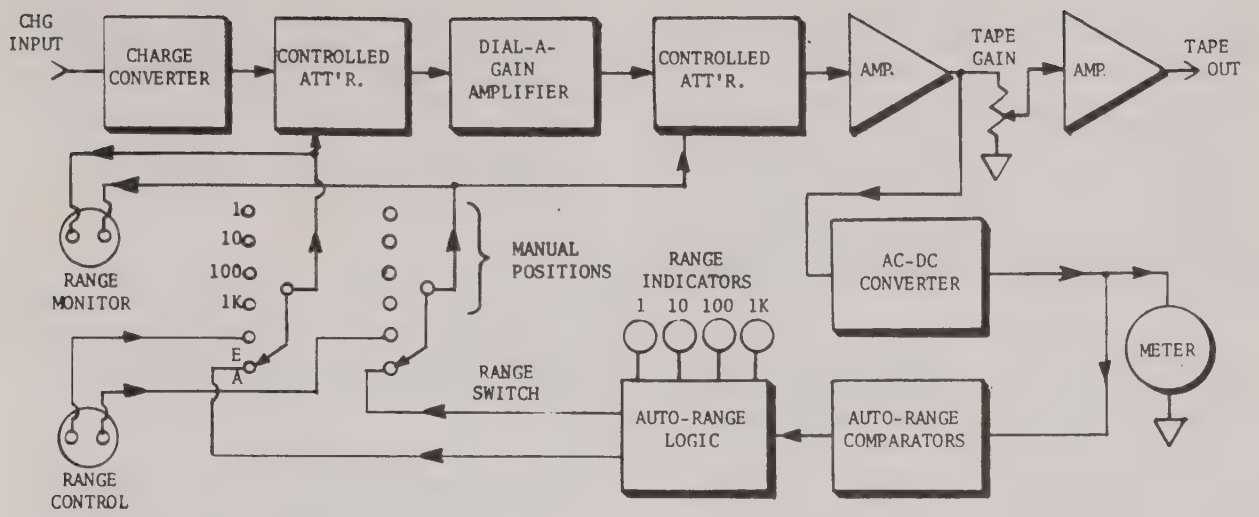


FIG. 7 BLOCK DIAGRAM MODEL D22PMA
AUTORANGING CHARGE AMPLIFIER

Fig. 7 portrays the block diagram of an instrument (U-D Model D22PMA) that serves equally well in large arrays or singly as a portable monitor. The availability of CMOS switches coupled with simple TTL logic, allows the full-scale range to be manually controlled, externally controlled by only two lines, or automatically controlled to the best of four different values. Transducer sensitivity normalization is accomplished by the conventional front-panel technique, and calibration (not shown) is accomplished by relay control. Two-line (binary signal) range monitoring is available for the manual, external, or automatic modes of range control.

Most FM recorders have a 45-50 dB dynamic range. Two-line control or monitoring provides four ranges at 20 dB intervals. This allows an 80 dB range of signals to be recorded, with the minimum recorded signal 25-30 dB above the noise floor of the recorder.

Storage of transducer sensitivity information in a computer for the purpose of compensating data amplitudes appropriately or for the purpose of digitally controlling a compensating circuit in the instrumentation channel is a waste of computer memory or a gross waste of control lines. Normalizing instrument gain to 1% accuracy for a 100:1 range of transducer sensitivities can require from 7 to 13 lines per channel, depending on the method used.

For large arrays, it is much simpler to use accelerometers with closely adjusted sensitivities. A typical example is the U-D Model 10B10 with a charge sensitivity of 10 pC/g ±1%. The sensitivity settings can then be made and locked on all instruments to identical values. Replacement or interchange can be done without affecting system accuracy, and without causing possible errors due to system parameters failing to be reprogrammed or reset.

For each array only one additional line is required to trigger the relay power supply and cause simultaneous full-scale calibration for all channels in the array. For large arrays the number of external range control and/or monitoring lines can be reduced further, because one instrument can be connected to control the full-scale range of several others in a master-slave arrangement.

5. LOW FREQUENCY, LOW AMPLITUDE MEASUREMENTS

Modal testing of large structures often requires the detection of low-frequency mode shapes at necessarily low acceleration values. This also means that the noise level of the transducer and signal conditioning device must be exceptionally low.

A new solution to this problem (U-D Model 500PA) involves close coupling a high-sensitivity piezoelectric accelerometer and an exceptionally low-noise voltage amplifier in a single housing. The accelerometers are carefully screened for minimum sensitivity to thermal transients, and are of shear design to assure insensitivity to base bending and case effects. The voltage

amplifiers have exceptionally low noise and exceptionally low input leakage current to allow flat frequency response to 0.1 Hz (3dB down at .01 to .02 Hz).

The overall sensitivity of the active transducer is from 0.5 to 1.0 V/g and can easily be adjusted to a tolerance of ±1%. The four-wire connection to the transducer supplies positive and negative power supplies, signal output, and signal reference. Since the output impedance of the preamplifier is low, an inexpensive cable can be used which is abuse-resistant, and triboelectric noise is negligible.

The signal conditioner can be a relatively inexpensive device which provides the power supply voltages, different full scale ranges, and low-pass filtering. Full-scale ranges of .01g to 10g are typical with a wideband equivalent input noise of 3×10^{-5}g rms from 1 Hz to 2 kHz. The frequency response of the conditioner must also be flat from 0.1 Hz to the desired upper frequency.

6. DIRECT-COUPLED DIFFERENTIAL AMPLIFIERS

Direct-coupled differential amplifiers find wide application for use with thermocouples, piezoresistive accelerometers, and strain gage bridges. Bridge transducers are used to provide means for measuring accurate zero frequency response as well as for simulating variables that are not physically measurable with a single strain gage, such as shear strain.

Features

A direct-coupled differential amplifier that is designed primarily for bridge transducers should have several additional features in addition to meeting typical specifications for a differential amplifier. These features include:

(1) Internal provision for bridge completion resistors so that bridges with 1, 2 or 4 active arms may be used. Preferably the bridge completion resistors are on a plug-in card.

(2) Inclusion of an accurate, highly-regulated low-noise constant-voltage power supply for excitation of the bridge. Several switch-selected values of voltage are desirable. Occasionally accurate constant-current excitation is requested.

(3) Additional connections for remote voltage sensing so that the accurate power supply voltage is maintained at the bridge to eliminate long-line effects.

(4) Additional connections for single shunt calibration. The total number of connector terminals to the bridge can be at least 8, plus shield to accommodate the four bridge connections, remote voltage sensing and calibration connections.

(5) Provision for user - selection of the shunt calibration resistors.

(6) A means for normalizing the instrument gain with respect to the transfer ratio or sensitivity of the bridge. This allows quick calibration of the instrument in terms of the full scale value (in eu) shown on the range switch. A technique for this is indicated later in this section.

Important Specifications

Important specifications for the differential amplifier include input impedance, pump-out current, zero drift, zero stability, noise, common mode characteristics, and frequency response. These specifications are discussed in some detail in the following paragraphs:

(1) The input impedance can vary from 10^6 to 10^9 ohms typically. Generally, the higher the input impedance, the lower the pump-out current, and the better the common mode rejection (CMR) for unbalanced source impedances.

(2) The pump-out current is direct-current emanating from the input terminals. It can vary from less than 1 nanoampere (nA) to 100 nA. The pump-out current determines the amount of internal bridge balance correction necessary for unbalanced source impedances. The differential temperature coefficient of pump-out current can affect zero drift for high bridge resistances.

(3) Zero drift is an extremely important specification which is usually given in terms of voltage drift per degree temperature change with two components: one RTI and the other RTO. Sometimes the drift is specified in terms of percent of full-scale deviation per degree temperature change, but this can always be converted to the voltage specification. Typical specifications vary from:

0.1 μV/°C RTI ± 20 μV/°C RTO

for chopper stabilized amplifiers to:

10 μV/°C RTI ± 1 mV/°C RTO

for less expensive amplifiers using close thermal compensation. It is assumed that the maximum gain of most bridge conditioners is at least 1000.

(4) Zero stability gives the long-term stability of the amplifier over typically an 8 or 24 hour period, at constant ambient temperature. Typical specifications vary from:

±1 μV RTI ±100 μV RTO over 200 hours for chopper-stabilized amplifiers to:

± 40 μV RTI ± 10 mV RTO for 24 hours for less expensive amplifiers using monolithic input stages.

(5) The noise specification is usually given in at least two parts to account for the

increased spectral levels at very low frequencies. In a sense, the long-term stability specification can be considered to be a very low frequency noise specification. Typical specifications vary from:

3 μV rms for 100 kHz bandwidth and 2 μV peak-to-peak for 10 Hz bandwidth for chopper-stabilized amplifiers. (Both RTI).

5 μV rms for 10 Hz to 10 kHz band and 10 μV peak-to-peak for 0.1 to 10 Hz bandwidth for monolithic input devices (both RTI)

The component RTO varies from 1 mV to 6 mV rms depending on the upper frequency limit (usually 10 kHz to 100 kHz)

It is necessary to note that the zero stability specification must be larger than the low frequency noise specification above to be meaningful. Also, an extremely low specification of zero drift is not very useful for an instrument which does not have correspondingly good specifications for zero stability and noise. In other words, a zero drift of 0.1 μV/°C RTI would not be very useful with an instrument with 10 μV p-p low frequency noise.

(6) The specification of common-mode characteristics usually has two major parts: the rejection-ratio (CMRR) and the maximum common-mode voltage (CMV). The CMRR is usually specified at maximum gain. Typical values of CMRR vary from 80 dB to 130 dB over the frequency range from 0 to 60 Hz. The maximum common-mode voltage varies from ±10V to 350V.

The specification is necessary to insure good rejection of power frequency voltages induced in the cable connecting the bridge to the conditioner, as well as the large static operating voltages for the bridge. The common-mode voltage should be at least as large as the maximum bridge supply voltage.

Gain Normalization

An accurate internal power supply for exciting the bridge is an important feature in order to provide gain normalization. It allows the bridge sensitivity to be quickly calculated. Consider the following example.

The output voltage ΔV due to a change in resistance ΔR of a single-active-arm bridge with element resistance R and excitation voltage V can easily be shown to be:

$$\Delta V = \frac{\Delta R}{4R} V \qquad (7)$$

The gage factor and bridge sensitivity are defined in Eqs (1) and (3), which are repeated below:

$$F = (\Delta R/R)/(\Delta L/L) \qquad (1)$$

$$S = \Delta V/(\Delta L/L) \text{ mV/1000 } \mu\varepsilon \qquad (3)$$

Substitution of (7) and (1) into (3) yields:

$$S = \frac{FV}{4} \qquad (8)$$

With more than one active arm, and identical gages:

$$S = \frac{(\text{active arms})FV}{4}$$

Calculation of bridge sensitivity is extremely simple and accurate, because both F and V are known accurately.

The sensitivity normalization circuit can follow the differential input circuit in the bridge conditioner. A ten turn locking dial and a two position range switch can easily provide normalization over a 100:1 range of input sensitivities.

CONCLUSION

This paper was prepared as a prelude to the revision of ANSI Standard S2.4-1960 by subcommittee S2-64 of the ANSI Committee on Mechanical Shock and Vibration.

REFERENCES

"Specifying the Characteristics of Auxiliary Equipment for Shock and Vibration Measurements" ANSI Standard S2.4-1960, American Standards Association, New York, N.Y. (1960)

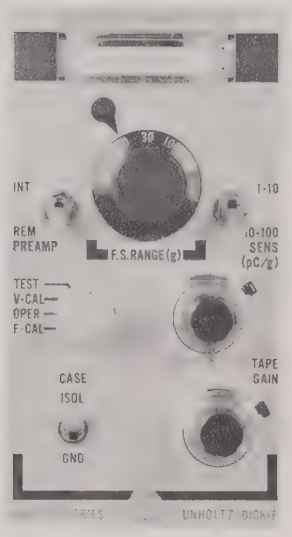
"Methods for Specifying the Characteristics of Auxiliary Equipment for Shock and Vibration Measurement" International Electrotechnical Commission Publication 222, Geneva, Switzerland (1966).

The "Basic"

MODEL D22PM
CHARGE AMPLIFIER

A General-Purpose Laboratory Instrument

- EXTREMELY LOW-NOISE OPERATION
- DIAL-A-GAIN SENSITIVITY NORMALIZATION
- CALIBRATED FULL-SCALE OUTPUT
- OPERATION WITH REMOTE PREAMPLIFIERS
- DIFFERENTIAL REJECTION OF GROUND SIGNALS
- PLUG-IN 3-POLE FILTER
- LOW POWER CONSUMPTION
- THREE CALIBRATION MODES
- INSENSITIVE TO EXTERNAL VIBRATION
- INDIVIDUAL SHIELDED POWER SUPPLIES
- WIDE VARIETY OF OPTIONS



The Model D22PM is the successor to the Model D11 line of instruments. The D22PM features plug-in card construction, extensive use of integrated circuits and rugged construction. Independent power supplies and shielded transformers are used so that individual operation is possible, grounding problems are minimized in large installations, and good power line isolation is provided.

In addition, separable references are provided for the input and output circuits so that an internal differential circuit can remove common-mode ground voltages caused by having the transducer case grounded at the point of measurement.

The Dial-A-Gain sensitivity normalization, originated by Unholtz-Dickie, allows the various outputs to be normalized for piezoelectric transducer sensitivities ranging from 0.5 to 100 pC/unit.

Being a charge amplifier, the gain of the D22PM is, of course, insensitive to input cable length.

NOISE

Extremely low output noise has been attained by careful selection of the input FET for the charge converter. Careful shielding, highly regulated power supplies and balanced circuitry keeps power frequency contamination extremely small. The built-in 3-pole low-pass filter can be selected to optimize the signal-to-noise ratio by proper knowledge of the expected signal spectrum.

Using the D22PM and the U-D Model 75D21 Accelerometer, with a relatively short low-noise cable, it is possible to achieve a typical noise level of 50 x 10^{-6}g rms over a 10 kHz frequency range. This means that acceleration levels less than .001 g may be accurately measured.

OUTPUTS

The standard tape output is calibrated to give exactly 10 V peak for full scale inputs for full clockwise rotation (10 turns) of the TAPE GAIN potentiometer. The locking dial accurately determines full scale output for other settings. The 1.24 inch scale edge-reading meter is calibrated in percent of full scale. Options include servo control (S) at 10 mV/g, a high-current driver for long lines or galvanometers (C or G), linear DC output (F), and logarithmic DC output (L).

RANGES

The maximum instrument gain, for a full scale range setting of 1 g and an input sensitivity of 1 pC/g, is 10 V/pC. Standard manual ranging provides seven full scale ranges from 1 to 1000 g in 1, 3, 10 steps, for input sensitivities from 1 to 100 pC/g.

The high gain option (-3) gives a maximum gain of 100 V/pC and nine ranges from 0.1 to 1000 g in 1, 3, 10 steps.

The external range control (E) and automatic-ranging (A) options described extensively in another bulletin provide four full-scale ranges: 1, 10, 100, and 1000 g. Two-line range control is possible for the E option and the best range is automatically selected for the A option. The E option also allows manual range control and the A option includes all the E option features.

FILTERS

A three-pole low-pass Butterworth filter is contained on a sub-plug-in board within the instrument. The instrument may be operated with the filter plug-in removed if desired. Other filter frequencies are easily and economically supplied.

CALIBRATION

The D22PM provides three calibration/checking Modes: F-CAL, V-CAL, and TEST. The F-CAL mode provides full scale output for 100 mV peak input regardless of range and sensitivity settings. The V-CAL mode provides an output dependent on all front-panel settings. The TEST mode inserts the calibration signal in series with the accelerometer cable shield. An open or shorted line is easily detected.

REMOTE PREAMPLIFIER

Remote voltage preamplifiers or charge preamplifiers such as the U-D Model 11PA-2 or Model 22CA-2, are accommodated by changing a front panel switch from INT. to REM. This allows the internal charge converter to be bypassed and means that standard low-cost coaxial cable may be used between the measurement site and the instrument. Triboelectric noise for long-line measurement is also avoided.

SPECIFICATIONS MODEL D22PM

1. GENERAL

1.1 Separate, isolated power supplies are provided in each channel

1.2 All power and signal connections are made at separate rear mounted connectors.

1.3 Each channel is totally enclosed so that it can be used with equal convenience as a bench mounted or as a rack mounted instrument.

2. INPUT CHARACTERISTICS

2.1 Charge input - direct connection to any piezoelectric transducer with 10 Megohms, or greater, shunt resistance.

2.2 Remote Preamp Input - two-wire connection to remote charge type or voltage type preamp that can be added to the system at anytime. The Preamp connector supplies the required bias voltage/current to the remote preamp.

2.3 Gain Change with Source Capacitance in Charge Mode (INT.) - A source capacitance of 50,000 pF shall cause less than 0.1% gain change for transducers having a sensitivity between 1 and 100 pC/unit.

2.4 Gain Change with Remote Preamp Mode (REM. PRE-AMP) - all instrument gain controls and range switches shall apply when operation is converted to the remote preamp mode. The basic instrument accuracy shall change by less than ±1%. Up to 2,000 feet of RG58/U coaxial cable shall cause a gain change of less than 1% when connected between the instrument and the remote preamp.

2.5 Maximum Input in Charge Mode (INT.)

±15,000 pC (1 to 10 pC/g.) ±150,000 pC (10 to 100 pC/g.)

3. OUTPUT

3.1 Tape Driver - Calibrated ±10 V peak at full scale condition into 1 K load. Ten turn locking potentiometer allows precision adjustment between 0 to 10 V. Output impedance less than 50 ohms direct-coupled.

3.2 Standard Meter - 1.24 inch scale meter calibrated in percent of full scale. Accuracy ±2% of full scale; average detector provided. Dual scale is available upon request.

3.3 Large Meter (Option "-8") - 2.5 inch scale length with 2 scales calibrated 0 - 10 and 0 - 3. Increases front panel height to 8-3/4 inches.

3.4 Servo Control (Option "S") - Output normalized to 10 mV pk/g pk, not dependent upon range switch position. No signal clipping occurs at the servo output at levels less than 100 g on any full scale range, and operates to 1000 g without clipping when placed on that range.

3.5 Galvanometer Driver (Option "G") - A high current amplifier provides a separate independent output with a current capacity of ±100 mA. Ten turn locking potentiometer allows precision adjustments between 0 and 10 V. Output impedance less than 1 ohm direct-coupled.

3.6 Log DC Output (Option L) - A DC output proportional to the logarithm of the input amplitude. The calibration constant is +1.0 V/decade and an output of 0 V DC is provided at full scale.

3.7 Velocity Integrator (Option I) - Output normalized to 100 ±10 mV-sec/in, not dependent on range switch position.

4. FREQUENCY RESPONSE

4.1 Low Pass Filter "Plug-In" Removed

±1% 10 Hz to 10 kHz ±5% 2 Hz to 30 kHz

4.2 Low Pass Filter "Plug-in" Installed - Plug-in component card supplied with unit is 3 pole maximally-flat Butterworth design. Filter frequency f_o can be supplied in 1, 2, 5, 10 sequence from 50 Hz to 10 kHz. Response at f_o is rated ±2% and at 2 f_o is -3 dB ±1 dB, with 18 dB/oct. attenuation rate.

5. RANGE SWITCHING

5.1 Standard - 1 to 1 K g full scale in 1-3-10 sequence for 1-100 pC/unit.

5.2 Option 3 - .1 to 1 K g full scale for 1-100 pC/unit in 1-3-10 sequence.

5.3 Option E - 1, 10, 100, 1000 g full scale controlled by front panel switch or by external 2-line binary control compatible with TTL logic. Logic 1 can be as high as +15 V.

6. MAXIMUM NOISE (RTI-referred to input; RTO-referred to output) All statements refer to 10 kHz low-pass filter, and 10 Megohm input resistance or greater.

   6.1 Standard Range Option - .005 pC rms plus .0015 pC rms/1000 pF source capacitance RTI for 1-10 pC/unit and .05 pC rms plus .0015 pC rms/1000 pF source capacitance for 10-100 pC/unit RTI plus 1 mV rms RTO.

   6.2 Range Option 3 - .005 pC rms plus .0015 pC rms/1000 pF source capacitance RTI for 1-10 pC/unit and .05 pC rms plus .0015 pC rms/1000 pF RTI for 10-100 pC/unit. plus 5 mV rms RTO.

7. CALIBRATION MODES

   7.1 F-CAL - provides full-scale output for 100 mV peak input independent of full scale range or sensitivity setting.

   7.2 V-CAL - connects calibration signal through precision 1000 pF ±½% capacitor directly to charge amplifier input providing 1 pC/mV conversion.

   7.3 TEST - connects calibration signal in series with shield of input cable.

   7.4 OPER - calibration signal disconnected for normal operation.

   7.5 Internal Oscillator (Option O) - provides calibration signal of 100 mV peak ±1% at 100 Hz. One oscillator can supply a total of six channels with patch cables supplied.

8. GROUND SIGNAL REJECTION - This input ground/output ground isolation feature allows the transducer case to be grounded at the test site without introduction of output due to ground loops.

   8.1 The output voltages normally created by ground loops due to grounded transducer cases are rejected by at least 60 dB at maximum instrument gain from 5 Hz to 1 kHz.

   8.2 The front panel range switch lamp verifies the correct position of the ISOL-GND front panel switch.

9. HARMONIC DISTORTION less than 0.5% and amplitude linearity is ±1% of best straight line.

10. POWER - Individual power supplies in each module; double-shielded power transformer; 100-130 V AC or 200/260 V AC; 50/60 Hz; 5 VA consumption

11. FRONT PANEL CONTROLS

   11.1 Full Scale Range Switch

   11.2 Mode Switch-Test; V-Cal; Oper; F-Cal

   11.3 Sensitivity Dial (10 Turn locking)

   11.4 Sensitivity Range Switch 1-10, 10-100

   11.5 Case Switch - Isol; Gnd. (Range Pilot)

   11.6 Preamplifier Switch - Remote; Internal

   11.7 Tape Gain Dial (10-turn locking)

12. PHYSICAL

   12.1 Single Module Standard - 2.8 W x 5.25 H x 19 D - requires Model 22RA Rack Adapter for multichannel mounting of up to six channels.

   Rack Adapter 22R: 19 W x 5.25 H x 21 D (6 modules)

   12.2 Single Module "-8" Option - 2.8 W x 8.75 H x 19 D - requires Model 22RA-8 Rack Adapter for multichannel mounting of up to six channels.

   12.3 Connectors are all coaxial BNC except for:

   Oscillator-Patch-miniature phone jacks - mating connector supplied

   12.4 Weight: Single module - nominal 6 pounds

   12.5 Operating Temperature: 40°F to 125°F

UNHOLTZ-DICKIE CORPORATION

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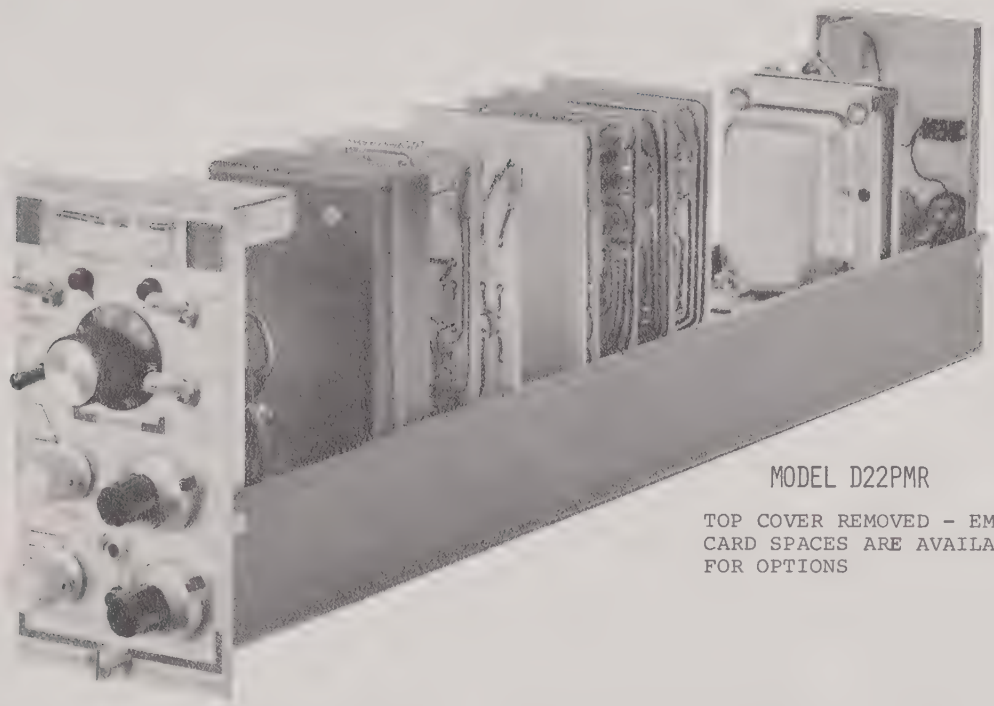
Area Code (203) 288-3358

MODEL D22 SERIES OPTION DESCRIPTIONS



MODEL D22PMR

TOP COVER REMOVED - EMPTY CARD SPACES ARE AVAILABLE FOR OPTIONS

The printed-circuit plug-in card construction of the D22 Series enhances the versatility of the instrument line. A large number of options are available. A definite description of each option is given below, except for the External Range Control (E) and Autoranger (A) options which are found on a separate bulletin D22-EA-74. For specific option availability with the D22PM "Basic", D22PMH "Red Hot", and the D22PMR "Multi", consult the table in Bulletin D22-74.

SERVO (S)

The servo (acceleration) output has a 10 mV/g sensitivity which is independent of the range switch setting. Output impedance is less than 50 ohms, and a maximum of ±10V at ±10 mA is available on at least one range with never less than ±1V available on all ranges (100 g). Standard frequency response is flat within ±2% to 5 kHz and 3 dB down at 10 kHz unless otherwise specified.

LOGARITHMIC DC OUTPUT (L)

A sensitivity of +1V per 20 dB of input change is provided, and 0V DC output corresponds to full scale sinusoidal inputs. A dynamic range of 60 dB is supplied with a stability and accuracy of ±0.2 dB from 0 to -40 dB and ±0.5 dB at -60 dB over a temperature range of 20° to 50°C. Averaging and conversion speed is dependent on the AC-DC converter associated with the meter feature, which is required. Operation down to 5 Hz is a minimum requirement.

The log DC outputs from two D22 Series instruments can be used with the differential Y input of an X-Y recorder to provide plots of transmissibility, apparent mass, or mechanical impedance if the appropriate transducers are used. A full output range of 120 dB can be obtained from two 60 dB instruments by using an averaging instrument (UD Model MAC-8) and a servo controller (UD Model SP Series). The combination maintains the average of the two variables at a constant value, but lets both instrument outputs fluctuate and yet never lets either output exceed twice the average control level. It is possible for both outputs to use the full 60 dB range and their ratio to have a maximum 120 dB range.

HIGH-CURRENT LINE DRIVER (C)

The line driver has a capability of ±10V or ±100 mA, whichever is limiting, to frequencies of 20 kHz. Capacitive loads may be driven under these limitations without causing oscillations. The frequency response is identical to that for the instrument. The output impedance is less than 0.2 ohm +.05 ohm/kHz. This output may be supplied at a fixed voltage for full-scale inputs, or may be coupled with the TAPE GAIN potentiometer for an adjustable full-scale output.

GALVANOMETER DRIVER (G)

The galvanometer driver is identical to the High-Current Line Driver (C) except that a separately-adjustable 10-turn potentiometer and locking dial is supplied on the front panel to provide a calibrated full-scale output.

VELOCITY (I)

The velocity output has an adjustable sensitivity from 100 to 110 mV-sec/in. Two pole high-pass filtering is built into the velocity integrator circuit to provide a flat frequency response ±2% from 5 Hz to 5 kHz and 3 dB (typ) down at 2.5 Hz. Output impedance is less than 50 ohms and maximum output capability is ±10V at ±10 mA. The servo (S) option is required also.

DISPLACEMENT (II)

The displacement output has a sensitivity of 1V/in. D.A. Two-pole high-pass filtering is built into the displacement circuit also. A flat frequency response ±3% at 5 Hz, ±2% 10 to 500 Hz, and 6 dB down at 2.5 Hz is provided. Output impedance is less than 50 ohms and maximum output capability is ±10V at ±10 mA. The servo (S) and velocity (I) options are also required.

SINGLE-ENDED HIGH-TEMPERATURE INPUT (K)

The option provides a modification on the D22 charge converter so that single-ended inputs from high-temperature accelerometers may be accepted without causing blocking for input shunt resistances as low as 10 kilohms. Note that the cable for differential accelerometers may be connected to provide a single-ended output to the D22.

Source capacitances of 20,000 pF will cause less than 1% gain change for transducer sensitivities from 1-100 pC/g. The frequency response at 5 Hz is flat ±5% with 50 kilohm shunt resistance. The acceleration noise with a 20 Hz (±2% and -3 dB at 10 Hz) high-pass filter is less than 0.05 pC rms referred to the input.

It is suggested that a choice of the K options be accompanied with the selection of a high-pass filter.

CALIBRATION OSCILLATOR (O)

The internal oscillator provides 100 mV peak ±1% at 100 Hz ±5%. When the D22 is placed in any one of the calibration modes (TEST, V-CAL, or F-CAL) the oscillator voltage is applied automatically to the circuit. By means of a rear panel miniature phone jack, the insertion of an external oscillator voltage automatically disconnects the internal oscillator. One calibration oscillator for each six D22 instruments (a full complement for a rack adapter) is sufficient since the output from one internal oscillator may be patched to the other five instruments.

TRACKING FILTER (T)

By means of two rear panel miniature phone jacks, the signal from the D22 may be fed through a unity-gain tracking filter (UD Model TF-11) and back into the D22 so that the D22 outputs (tape; meter; servo; high-current) represent the narrow-band signal. In this way, servo control can be obtained from the fundamental sine component, and the meter indication of the D22 can be used without purchasing additional meters. Removal of the tracking filter from the rear panel jacks automatically shunts the external connection and reroutes the signal properly in the D22.

SWITCHED HIGH-PASS AND LOW-PASS FILTERS

Front-panel-switched high-pass and low-pass filters are standard on the D22PMH. The filters supplied are typically Butterworth, having 3, 6 or 10 poles (18, 36, or 60 dB/oct attenuation). Typical filter specifications are below. The cutoff frequency is fc.

All Filters -3 dB ±1 dB at f/fc
flat ±2% at f/fc = 1

	HIGH-PASS			LOW-PASS		
Poles	3	6	10	3	6	10
f/fc	.5	.67	.8	2	1.5	1.25

The ±2% frequency is usually specified.

EXTENDED LOW FREQUENCY RESPONSE (-2)

This option provides the following low-frequency response for charge inputs (strain-gage inputs where applicable) at the servo, tape, high-current and meter outputs.

flat ±2% at 2 Hz
±5% at 0.5 Hz

ADDITIONAL (X10) GAIN (-3)

The gain is ten times that of the standard instrument (not available for D22PMR). Standard range switching with this option provides full scale ranges from 0.1 g to 1000 g for transducers with sensitivities from 1-100 pC/g. Note that a transducer with a sensitivity from 10-100 can be used on the 1-10 sensitivity range, thus providing full scale indication for inputs as low as .01 g. Nominal maximum instrument gain is 100,000 mV/pC.

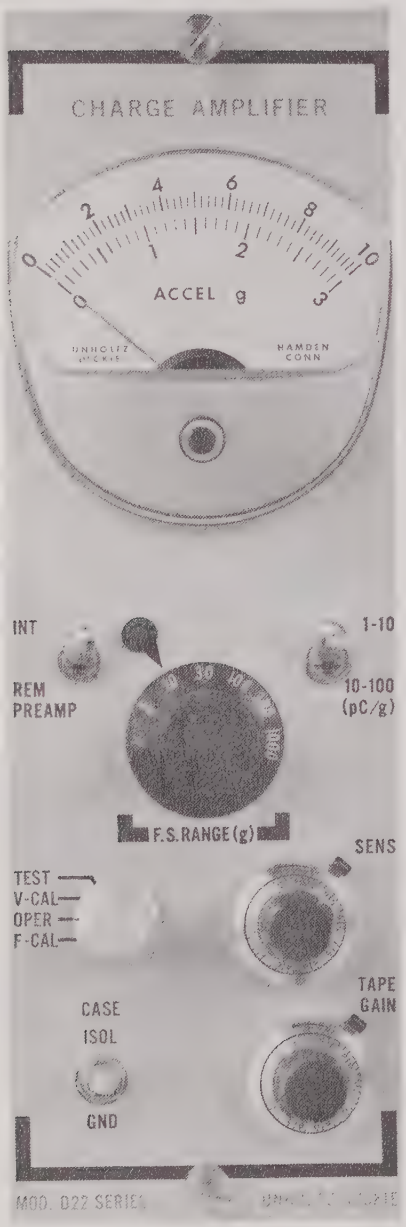
FULL SCALE RELAY CALIBRATION (-4)

Application of the relay control signal (+15V at 15 mA) to the rear-panel BNC connector causes full scale indication at the meter, tape, and high-current outputs, regardless of the range and sensitivity settings, if 100 mV peak is applied to the oscillator jack. This option quite logically accompanies the internal oscillator (O) option, whereupon triggering the relay causes full-scale output. The relay actuation overrides the mode provided by the manual mode switch.

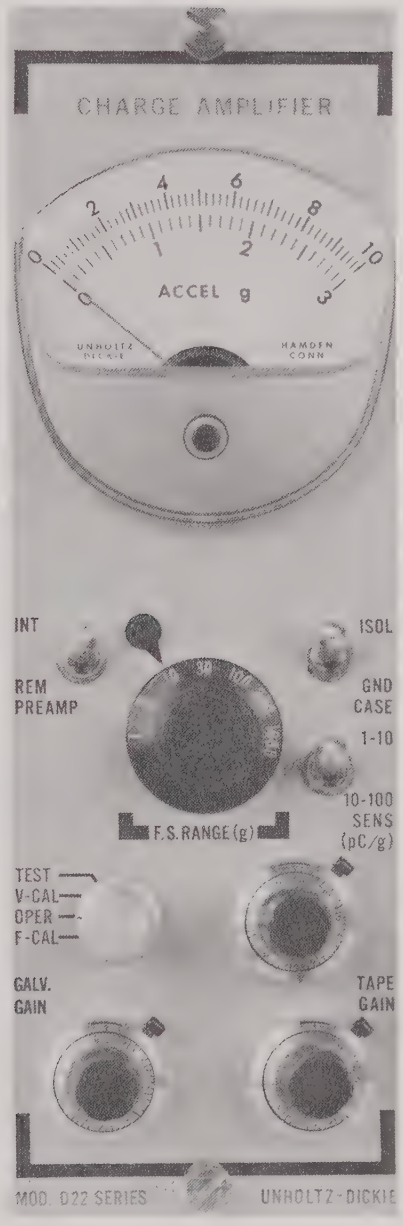
LARGE METER (-8)

A 2.5 in. scale meter is provided with a knife-edge needle for easier reading. Accuracy is ±2% of full scale. The panel height is 8.75 inches and the modules use the Model 22RA-8 Rack Adapter. See figures on page 4.

LARGE METER VERSIONS OPTION -8



MODEL D22PM-8



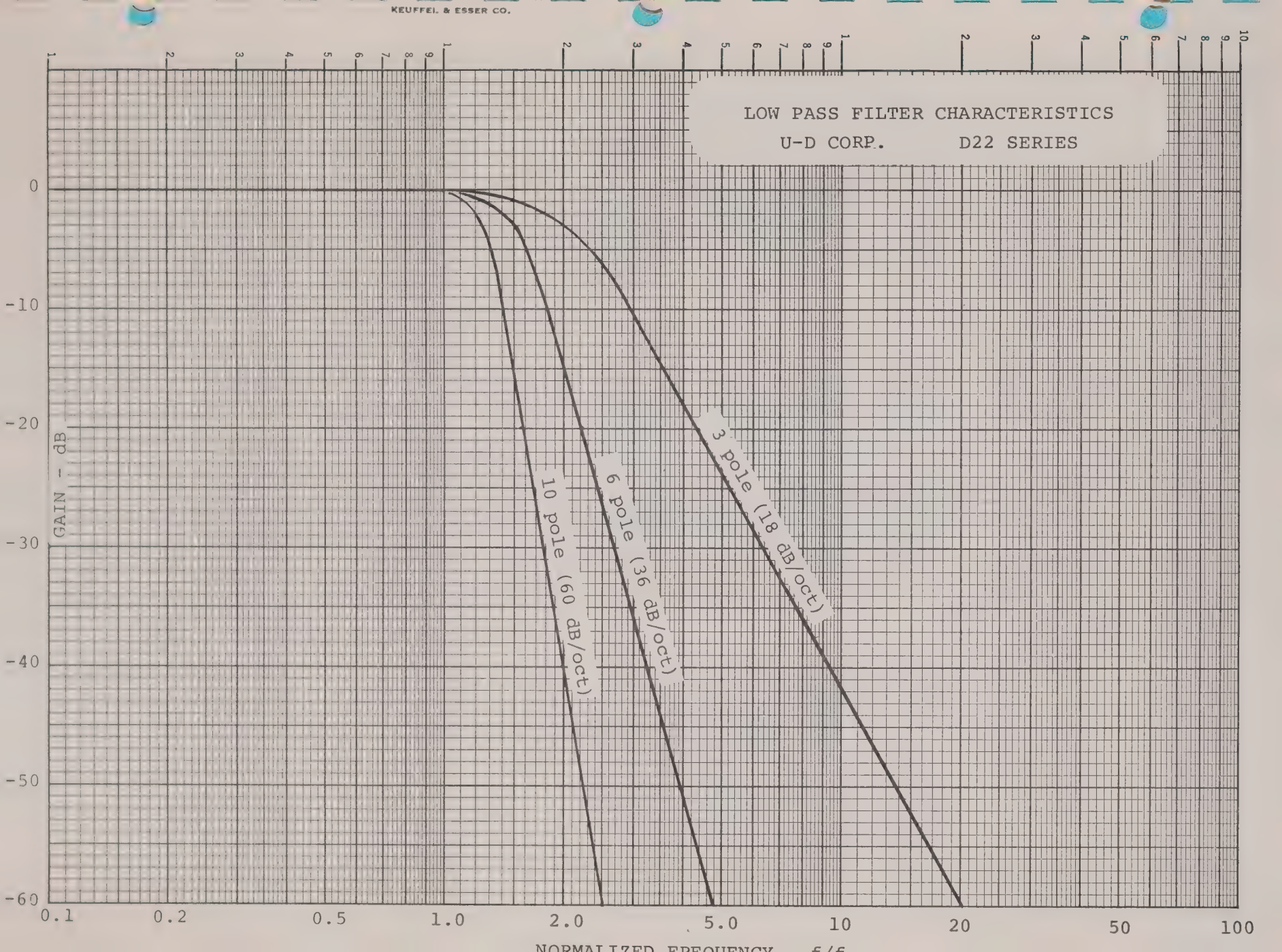
MODEL D22PMG-8

UNHOLTZ-DICKIE CORPORATION

2994 Whitney Avenue, Hamden, Connecticut, 06518

Area Code (203) 288-3358

KEUFFEL & ESSER CO.



MODEL D22 SERIES
SIGNAL CONDITIONING AMPLIFIERS

Three versatile amplifiers with ~~7~~ ~~10~~ many options

MODEL D22PM "BASIC"

MODEL D22PMH "RED-HOT"

MODEL D22PMR "MULTI"

A complete redesign and expansion of the signal conditioning line has resulted in amplifiers which satisfy three wide application areas. The D22PM, "Basic", is a charge amplifier which satisfies most standard laboratory needs. The D22PMH, "Red-Hot", is a high-performance charge-amplifier for use with high-temperature (differential) accelerometers. The D22PMR, "MULTI", operates in a charge or voltage mode with piezoelectric devices and in a voltage mode with strain-gage transducers. The circuit design makes extensive use of integrated circuits and plug-in circuit cards, which allow great versatility for adding options. Rugged modular construction allows separate operation or six units to a rack adapter in high noise environments.

COMMON FEATURES OF ALL THREE AMPLIFIERS INCLUDE:

- o Individual shielded power supplies
- o Extreme low-noise operation
- o Wide frequency range 2 Hz - 100 kHz
- o U-D originated DIAL-A-GAIN calibrated sensitivity normalization
- o Calibrated full-scale tape output
- o Differential rejection of ground loop signals
- o Operation with remote preamplifiers
- o Reduced heat load - typically 5 VA
- o Plug-in 3-pole low-pass filters
- o Several Calibration Modes

THE INDIVIDUAL AMPLIFIERS ADD THESE FEATURES:

"BASIC" D22PM

- o Low Cost
- o Guarded Charge Converter
- o Three Calibration Modes
- o Gain insensitive to cable capacitance
- o Options for driving long lines, providing transmissibility plots, controlling servos

"RED-HOT" D22PMH

- o Accommodates single-ended or differential accelerometers
- o Guaranteed noise performance for 50k input shunt resistance
- o Operable to 10k shunt resistance
- o Switchable 3-pole hi-pass and low-pass filters
- o Meter indication

"MULTI" D22PMR

- o Charge or voltage mode
- o Strain gages or piezoelectric devices
- o Simple sensitivity normalization for strain gages
- o Constant-current source for strain gages
- o Internal square-wave gage calibration check

The following table summarizes the outstanding features and helps user selection of options such as meters, log DC output, external range control, and autoranging. The Models D22PMS, D22PMGS, D22PMGSLTO, D22PMHS, and D22PMRS are normally factory stocked for short delivery. Other models are built to order and normally require a minimum order of six units.

LEGEND: S - Standard; O - Available Option; O* - Option Factory Stocked; N - Not Available; Z - Consult Factory For Availability

FEATURE/OPTION	OPTION LETTER/ NUMBER	"BASIC" D22PM	"RED-HOT" D22PMH	"MULTI" D22PMR	COMMENTS
Ground Loop Signal Rejection	D	S	S	S	
Internal/Remote Preamp	P	S	S	S	
Meter-Edge Reading ±2% F.S.	M	S	S	S	
1-10, 10-100 Sens. Ranges	-	S	S	S	
10 Turn Locking Sens. Pot	-	S	S	S	U-D Dial-A-Gain
10 Turn Tape Gain ±10V F.S.	-	S	S	S*	*±1V F.S.
Fixed Plug-In LP Filter	-	S	N	S	3-Pole Butterworth
In/Out Switch LP Filter	-	N	S	N	6 & 10 Pole Also Available
In/Out Switch HP Filter	-	N	S	N	6 & 10 Pole Also Available
Test, F-Cal, V-Cal Modes	-	S	S	N	
Diff. Accel. (Hi-Temp) Input	H	N	S	N	Includes K
Single Ended Hi-Temp Input	K	O*	S	O*	
Strain Gage, Charge, Volt Input	R	N	N	S	
10 mV/g Servo Output	S	O*	O*	O*	
100 mV-sec/in. Vel. Output	I	O	O	O	Requires S
1 V/in. DA Disp. Output	II	O	O	O	Requires S & I
Linear DC Output	F	O	O	O	
Log DC (1V/20dB) Output	L	O	O	O	Requires M
Manual Ranging 1-3-10 F.S.	-	S	S	S	
Remote Range Control (2 line)	E	O	O	O	4 Decade Ranges
Automatic Range Selection	A	O	Z	Z	Includes E, Requires M
High Current Line Driver ±100 mA	C	O	O	O	Current Booster For Tape Out
Independent Galvo Output ±100 mA	G	O*	N	N	Adjustable with 10T Pot.
Calibration Oscillator	O	O	O	O	100 mV pk at 100 Hz
Tracking Filter	T	O	O	O	Allows internal insertion
Freq Resp ±5% 2Hz to 30 kHz	-	S	S	S	
Extended Low Freq. ±5% 0.5 Hz	-2	O	O	O	
Extra X 10 Gain	-3	O	O	N	.01 g F.S. For 10-100 Sens
Full-Scale Relay Calibration	-4	O	O	O	
Large 2½" Scale Meter	-8	O	Z	Z	8.75 In. Panel Height

UNHOLTZ-DICKIE CORPORATION

2994 Whitney Avenue, Hamden, Connecticut, 06518

VIBRATION TEST EQUIPMENT

- VIBRATION TEST SYSTEMS
- VIBRATION TRANSDUCER CALIBRATION SYSTEMS
- RANDOM ACCESSORIES
- COMBINED SLIP TABLE ASSEMBLIES
- AUTOMATIC SINE CONTROLS
- LOW COST TRACKING FILTERS
- SIGNAL CONDITIONING AMPLIFIERS
- ACCELEROMETERS

manufacturers of shaker systems, advanced instruments and accelerometers

UNHOLTZ-DICKIE CORPORATION

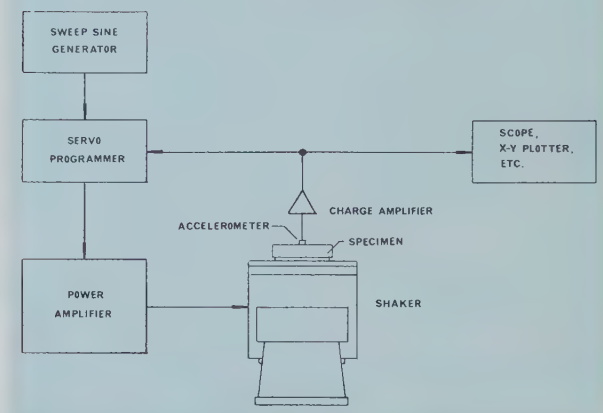
3000 WHITNEY AVE. / HAMDEN, CONN. 06518 / (203) 288-3358

INTRODUCTION

Vibration testing has been a major tool used in the development of military and space hardware for over 25 years. Today, the benefits of vibration testing are being applied in a variety of commercial and consumer product areas as well. This trend parallels an increasing number of federal regulations which require more comprehensive testing to assure product reliability and safety.

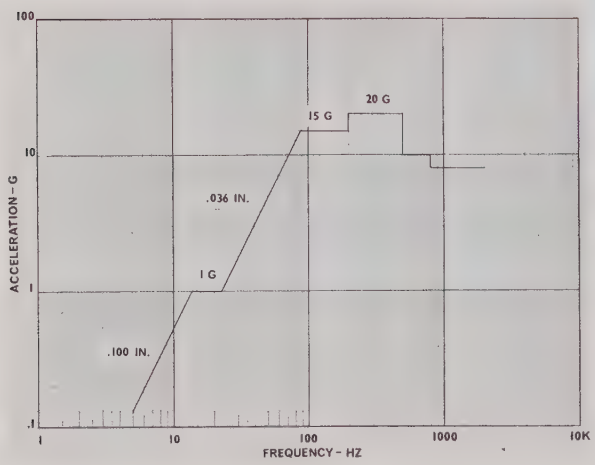
Vibration testing can genuinely benefit the manufacturer. By simulating environmental vibration levels during actual product development, the engineer can verify that a design is suitable for its application. This type of testing establishes performance and reliability prior to release of a design for production. Such an approach can save money by minimizing the probability of major redesign work, and even legal liabilities which may result from an inadequate product design. In addition, quality control procedures can be enhanced by using vibration testing as a tool to monitor the consistency of production methods and materials.

Figure 1. **SETUP FOR AUTOMATIC SINE TESTING**



Electrodynamic shaker systems are used in a variety of test applications. A typical arrangement for automatic sine testing is shown in FIG. 1. Such a setup provides automatic frequency cycling at preselected vibration levels, under servo control. A typical test "program" is shown in FIG. 2.

Figure 2. **EXAMPLE OF TEST PROGRAM**



The block diagram above could represent any of a wide variety of available vibration test systems. Unholtz-Dickie, the industry leader in solid state powered shaker systems, offers a complete line of vibration test systems as well as a full complement of signal conditioning and control instrumentation. See page 3 for a convenient listing of Unholtz-Dickie shaker systems. The remaining pages describe many of the instruments and system accessories that have helped make Unholtz-Dickie today's number one manufacturer of vibration test equipment.

The purpose of this short form catalog is to summarize the standard vibration test equipment manufactured by the Unholtz-Dickie Corporation. Detailed information on the many systems and related accessories is available on request.

VIBRATION TEST SYSTEMS

Unholtz-Dickie produces vibration test systems for all test applications. Sine force ratings range from 50 to 20,000 pounds. The table below lists these systems, with pertinent technical data. Special systems, including those with multiple shakers are also available.

Every Unholtz-Dickie system includes a safe, reliable, proven solid state power amplifier, and features reliable air cooling of the shaker armature. Systems engineering of each system element assures maximum performance and utilization, with simplified operation.

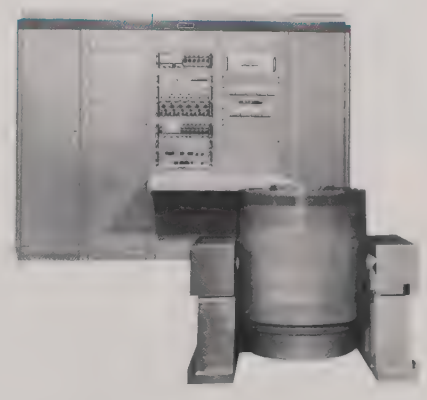
SYSTEM PERFORMANCE				SHAKER	
FORCE (lbs)		STROKE (inches, DA)	MAX. SINE PAYLOAD (lbs) at 20g	ARMATURE WEIGHT (lbs)	TABLE DIA (inches)
Sine (pk)	Random (rms)				
50	—	0.5	1.8	0.69	2
50	—	1.0	1.9	0.55	drive rod
150	—	4.0	5.2	2.25	drive rod
250	125	1.5	9.7	2.75	3.5
300	180	1.5	12.2	2.75	3.5
500	300	1.0	19.7	5.3	4.5
1,000	—	6.0	39	11	drive rod
1,200	600	1.0	46	14	5.75
1,200	600	1.0	40	20	8
1,700	850	1.0	65	20	8
3,000	2,200	1.0	134	16	5.75
3,000	2,200	1.0	128	22	8
3,800	2,200	1.0	162	28	8
6,000	3,000	1.0	264	36	12
6,000	4,500	1.0	264	36	12
8,000	4,000	1.0	310	90	16
12,000	6,000	1.0	510	90	16
12,000	8,000	1.0	505	100	16
17,500	12,000	1.0	780	95	16
17,500	15,000	1.0	780	95	16
19,500	14,000	1.0	880	95	16
20,000	18,000	1.0	905	95	16

INDUCT-A-RING

The Unholtz-Dickie INDUCT-A-RING Shaker features a solid metal, single turn armature coil for maximum reliability in a high performance machine. AC currents are induced into the metal ring, eliminating the need for current connections to the armature. This exclusive air cooled armature provides unmatched ruggedness and service life. INDUCT-A-RING Shakers are available in 12,000 pound force systems and up.

SOLID STATE POWER

Unholtz Dickie pioneered the use of solid state power amplifiers for driving electrodynamic shakers. The present design has demonstrated reliable performance since early 1968. No power transistors since introduced on the market offer the promise of better performance and reliability. Today, amplifiers with output ratings to 200 kVA are offered. Direct coupling to the shaker provides superior low frequency performance, such as 1 inch peak-to-peak displacement at 2 Hz, as required by some MIL-STD-810B procedures.



19,500 pound system with 120 kVA solid state power amplifier and INDUCT-A-RING Shaker, shown with optional instrumentation.

SERIES 300
VIBRATION TRANSDUCER
CALIBRATION SYSTEMS

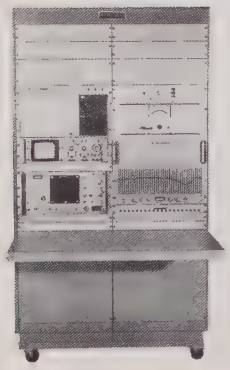
The Series 300 Calibration Systems are offered with manual controls for point by point calibration, or with frequency sweeping controls giving an automatically drawn curve of % deviation of the "unknown" transducer sensitivity relative to the "reference" accelerometer, as a function of frequency. Original data is permanently plotted, eliminating operator errors in readout and transcription.

At full system performance, and with automatic servo controls operating, acceleration waveform distortion is less than 1.5% at all operating frequencies. The overall system noise level is less than .005 g rms. Automatic plotting systems feature 0.25% plotting resolution of the unknown transducer output relative to the reference.

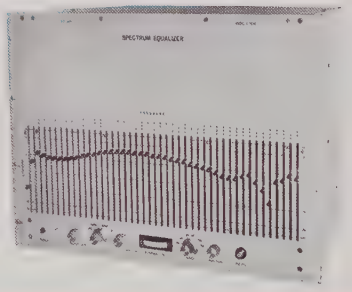
Model 351

Automatic Recording Vibration Calibration System with Optional VI100 Shaker Vibration Isolation

RANDOM ACCESSORIES



Complete random testing capability is available with systems-engineered random controls. A typical remote random control console configuration is shown here.



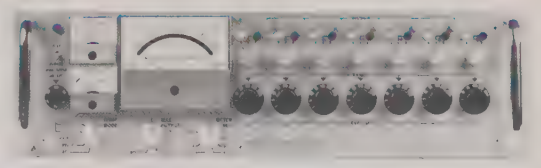
Random Accessories include the Model E109B Spectrum Equalizer, featuring 45 active filters with individual, rectilinear motion attenuation controls. Convenient equalization can be performed using this unit in conjunction with a real time analyzer.

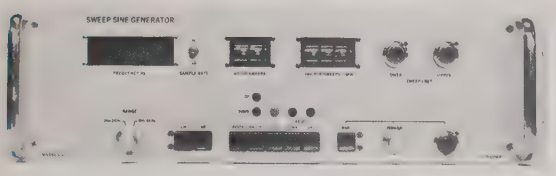
PERMALINE
COMBINED SLIP TABLE ASSEMBLIES

The PERMALINE Combined Slip Table Assembly provides for testing in three axes while using only one fixture. Permanent factory alignment of the shaker and slip plate allows quick change from vertical to horizontal operation. In addition, no special floor construction is required since inflatable air mounts effectively isolate the entire assembly from the supporting structure.

AUTOMATIC SINE CONTROLS

Model SP-7 Servo Programmer features amplitude servo, vibration meter, seven segment programmer, and optional charge amplifier for automatic, multi-level sine testing. All controls are interlocked to prevent damage to the test specimen. Model SP-2 Servo Programmer features two segment programmer.





Model OSC-1 Sweep Sine Generator is systems engineered to provide the vibration test system input sine wave signal for continuous cycling over a 3-decade frequency range. Unit features digital counter frequency display that can count and display ten times per second regardless of the operating frequency.

SPECIAL CONTROLS

Model AM-122 Acceleration Monitor and Limiter offers independent vibration system overtest protection in the event of equipment failure or misoperation of the system control channel. Shutdown is obtained by use of an adjustable meter relay and solid state signal conditioning circuitry.

Model TF11 Tracking Filter features a constant 10 percent bandwidth between the limits of 2 and 200 Hz, plus a standard log DC output for X-Y plotting. All this in a compact unit, at an attractive price.

Model MAC-8 Multifunction Averaging Control features eight individually selectable data channels for control to the average signal level. Can be used for sine or random vibration testing.

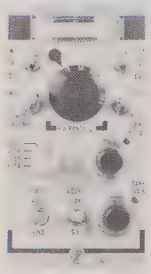
Model RD-1 Resonant Dwell Control automatically maintains the vibration testing frequency at the resonant frequency of a test specimen during endurance testing.

Model ACS-6 Acceleration Control Selector automatically switches to the highest (or lowest) acceleration input. Accepts six sine acceleration signals, and gates to the output whichever signal reaches its preset limit.

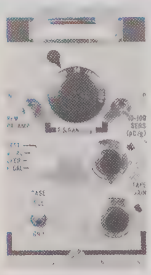
SIGNAL CONDITIONING AMPLIFIERS

D22 SERIES

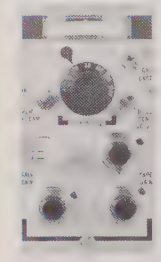
The D22 Series provides charge amp signal conditioning for all piezoelectric transducers. Some models also provide for strain gage operation. This series features all integrated circuit design with superior low noise characteristics, in a rugged modular construction. The basic Model D22PM includes the capability of operating with a remote preamp, and includes a meter. This and other standard models are shown below. The wide range of optional features available for addition to most models, is listed below.



D22PMH



D22PM



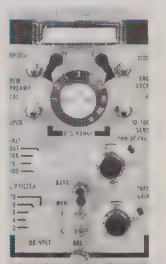
D22PMG

D22PMA

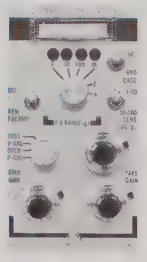
D22 OPTIONS

Description	Suffix
STRAIN GAGE OPERATION	R
HIGH TEMP ACCEL. INPUT	H
BRIDGE CONDITIONER	B
10 mV/g SERVO OUTPUT	S
100 mV-SEC/IN. VEL. OUTPUT	I
1 V/IN. DA DISP. OUTPUT	II
LINEAR DC OUTPUT	F
LOG DC OUTPUT	L
REMOTE RANGE CONTROL	E
AUTORANGING	A
±100 mA LINE DRIVER	C
±100 mA GALVO OUTPUT	G
CALIBRATION OSCILLATOR	0
TRACKING FILTER CONNECTION	T
0.5 HZ FREQ. RESPONSE	–2
EXTRA X10 GAIN	–3
FS RELAY CALIBRATION	–4
LARGE 2½" SCALE METER	–8

D22PMR

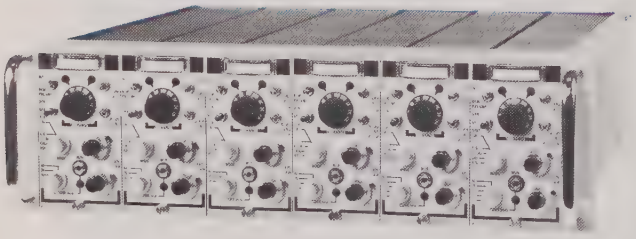


D22PMB



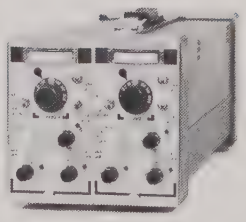
D22PMGA

P22MS



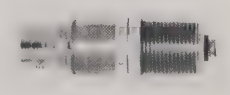
22RA

The Model 22RA Rack Adapter accepts six 22 Series modules in the standard 5¼ inch panel height. Also accepts the Model TF11 Tracking Filter (see page 5).



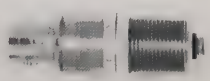
22P2

The Model 22P2 Dual Channel Portable Adapter accepts two channels of 22 Series instruments.



11PA-2

The Model 11PA-2 is a two-wire Remote Voltage Preamp designed for use with any of the 22 Series instruments.

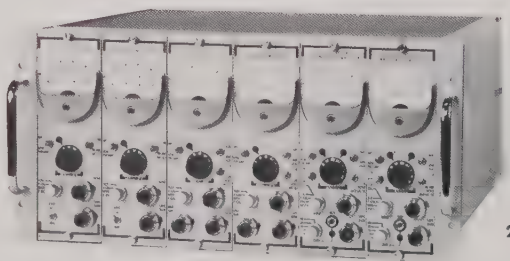


22CA-2

The Model 22CA-2 Remote Charge Preamp may be used with any of the 22 Series instruments shown above, and is a companion unit to the Model P22MS. Optional Model 22CA-2T is available for operation to 160°F.

D22PM-8

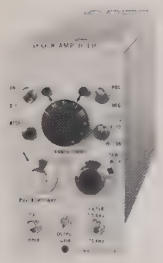
Models D22PM and D22PMR are available with the "–8" option, which provides a 2½ inch meter scale for easier readout.



22RA-8

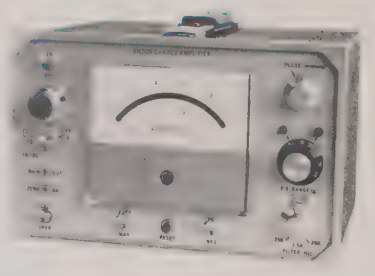
Rack mounted D22's with the "–8" large meter option require the 22RA-8 Rack Adapter with 8¾ inch panel height. Each 19 inch adaptor accepts six "–8" modules.

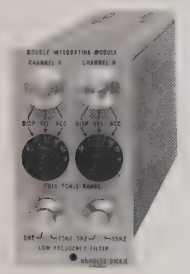
SIGNAL CONDITIONING PRODUCTS



Model SA22 Shock Charge Amplifier measures shock pulse durations from 100 microseconds to 500 milliseconds and pulse amplitudes up to 100,000 pC peak.

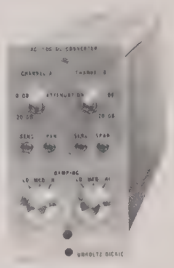
Model SA22TPM Portable Shock Charge Amplifier provides the same shock pulse measurement capability as the SA22, but also features a Transient Peak Meter for retaining peak g readings.



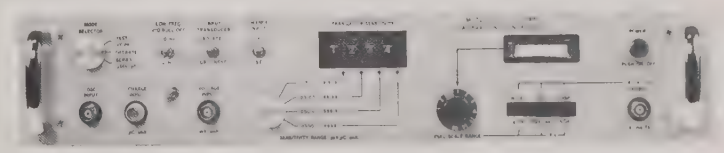


Model AVD-22M provides two channel, double integration of conditioned 10 mV/g acceleration signals. Each channel has tape and X-Y plotter outputs, plus normalized velocity and displacement outputs. Unit features 80 dB dynamic range and switchable low frequency filtering.

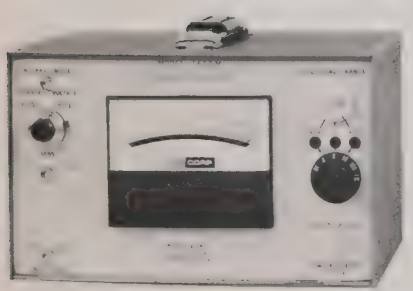
Model CV22PM-LF1 charge/voltage amplifier, operates down to 0.1 Hz. Combines capabilities for low level, low frequency vibration measurements and long duration shock pulse measurements.



Model LDC-22 provides two channel conversion to log DC of conditioned 1V peak full scale input signals for X-Y plotting. Features 5-10,000 Hz frequency response, 60 dB dynamic range, and selectable damping.



Model 1611 Precision Charge/Voltage Calibration Standardizer features typical ¼ percent overall instrument accuracy and stability. Frequency response from 2 Hz to 20,000 Hz. Used in transducer calibration systems, or wherever maximum accuracy is required.



Model 1610 Series Double Integrating Charge/Voltage Monitors are available in three standard models: 1610M (single channel, portable) 1610RM (single channel, rack mounted), and 2610 (dual channel, rack mounted). Switch selectable outputs for acceleraton, velocity, or displacement are provided along with log scale meter readout. Log DC and variable gain galvo outputs are optionally available.

ACCELEROMETERS

Unholtz-Dickie produces a full line of piezoelectric accelerometers for general purpose vibration testing and for special applications. Various models are optimized to provide features such as subminiature size, high sensitivity, high frequency operation, and normalized 10 pC/g sensitivity.

MODEL	PERFORMANCE FEATURES	NOMINAL: OPEN-CIRCUIT VOLTAGE SENS. mV-pk/g-pk	NOMINAL: CHARGE SENSITIVITY pC-pk/g-pk	NOMINAL: USEFUL FREQUENCY RANGE-Hz	NOMINAL: SIZE-INCHES WEIGHT-GRAMS	DESIGN FEATURES
2E3	**Subminiature, extremely small,** lightweight, for highest frequencies and minimum added mass.	2.5	1.0	1.0 TO 12000	HT .310 DIA .220 WT 1.22	Shear, side connector, integral cable, molded neoprene strain relief boot, adhesive mount, lead zirconate-titanate crystal. 2E5 has wrenching flats for easy removal.
2E5	Relatively large voltage and charge outputs. Low base strain sensitivity construction.				HT .310 DIA .280 WT 1.36	
2D21	**Subminiature, lightweight,** with low base strain sensitivity construction. Removable cable.	3.0			HT .415 HEX .280 WT 1.31	Shear, top connector, wrenching flats for easy removal, lead zirconate-titanate crystal.
5D21-8	**Miniature, general purpose,** moderately high resonance, low base strain sensitivity, recommended for charge use.	5.0	8.0	0.2 TO 7000	HT .64 DIA .50 WT 10.7	Shear, top connector, 10-32 mounting hole, lead zirconate-titanate crystal. Stainless steel case.
10DQ21	**General purpose,** side connector for restricted height applications. Low base strain sensitivity.	20	40	0.2 TO 6000	HT .71 HEX .62 WT 25	Shear, side connector, 10-32 mounting hole, lead zirconate-titanate crystal. Stainless steel case.
75D21	**Maximum voltage and charge sensitivity** gives best signal/noise ratio for low level measurements. Low base strain sensitivity.	75	82	0.3 TO 4000	HT .74 HEX .75 WT 37	Shear, top connector, 10-32 mounting hole, lead zirconate-titanate crystal. Stainless steel case.
10B10	**Charge sensitivity normalized** at 10 pC/g. Wide temperature range, −300°F to +500°F. Flat voltage and charge sensitivities. Low base strain sensitivity.	3.1	Set at exactly 10.0	1.0 TO 4000	HT .78 HEX .62 WT 27	Double base, compression, side connector, 10-32 mounting hole. Bismuth strontium titanate crystal. Stainless steel case.
10B10T					HT .81 HEX .62 WT 29.5	Same as 10B10 but with top connector.
A-1 Probe	**General purpose** hand-held accelerometer for vibration survey.	3.5	5.2	0.3 To 600 (hand-held)	LGH 5.25 DIA .62	Shear mode, hand-held, aluminum case with stainless steel tip.
1000 PA	**High sensitivity, low noise,** and low output impedance permit very low level measurements at low frequencies. Excellent signal/noise ratio is maintained even with long runs of low cost cable.	1000	NA	0.1 TO 2000	LGH 1.0 WD 1.0 HT 2.06 WT 110	Shear mode, with integral electronics and 4-pin side connector. 10-32 mounting hole or optional magnetic base. Sealed aluminum case.
100 PA		100				

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UNHOLTZ-DICKIE CORPORATION

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Printed in USA

SF-11-74

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WARRANTY

All products are warranted to be free of defects in material and workmanship for a period of one year from date of shipment. If the product is not installed, maintained and used in a normal manner in accordance with instructions and manuals, this warranty will not apply. Commercially available instruments and accessory items purchased and installed in the product will carry the original manufacturer's warranty.

This warranty is limited to repairing or replacing parts which have been returned and in our opinion are defective. Service required to correct defects in material or workmanship will be supplied without charges. The Buyer will pay all transportation and taxes incurred. This warranty does not cover any costs incurred by the Buyer as a result of purchase of UNHOLTZ-DICKIE CORP. equipment or any charges for the Buyer's labor for replacement, adjustment or repair unless authorized in advance in writing. We are not liable for consequential damages.

This warranty will not apply to any products which, in the opinion of UNHOLTZ-DICKIE CORP., have been subject to accident, misuse or neglect; altered or repaired with a substitute which might impair the product; or used outside of rated conditions. UNHOLTZ-DICKIE CORP. reserves the right to make improvements in its products including changes and additions without incurring obligations to incorporate such improvements in previous units.

This warranty is expressly in lieu of any and all other warranties or commitments, expressed or implied and any other obligations to the Buyer associated with the use of UNHOLTZ-DICKIE CORP. products.

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UNHOLTZ-DICKIE CORPORATION

Incoming Instrument Inspection

and

Return Shipping Instructions

1. Unpacking and Inspection

If the shipping carton is damaged, note on acceptance that it is received damaged and subject to claim when inspected. Ask that the carrier's agent be present when the instrument is unpacked and inspected for damage (scratches, dents, broken knobs, etc.). If the instrument is damaged or fails to meet specifications, notify the carrier and the Unholtz-Dickie Corporation immediately. Retain the shipping carton and the padding material for possible return for repair or further inspection by carrier. The purchaser and Unholtz-Dickie Corporation will arrange for the replacement and/or repair of the damaged item.

Refer to our separate warranty page for a statement of our warranty policy.

2. Return Shipment

Return shipment procedure: Please be sure the following instructions are observed if a Model 22 Series instrument is being shipped back to Unholtz-Dickie for repair, replacement, or upon completion of use as a demonstrator or loaner.

2.1 Size of Box and Packing Instructions

2.1.1 Single Channel with 5¼ inch Panel Height

If the single channel was shipped from Unholtz-Dickie as an individual unit, replace the instrument in its original container. If the instrument was shipped as part of a rack mounted combination of channels, the single channel can be returned separately in a container that is no smaller than 22½ inch x 10½ inch x 9½ inch. The front and rear panels must be completely protected by approximately 2 inches of cushioning material. The top, bottom and sides must be surrounded by cushioning and filler materials. A strong, double wall type corrugated box, (350 lb/sq. in. minimum bursting test) has been proven to give adequate service. DO NOT USE A SMALLER OR WEAKER CONTAINER THAN THAT RECOMMENDED ABOVE.

Cover the painted surfaces of the instrument with protective wrapping paper or a plastic bag whenever the packing material might be coarse enough to scratch the painted surfaces.

2.1.2 Six Channel Rack with 5¼ inch Panel Height

CAUTION: Do not rest the rack type instrument in a vertical position with its weight on the rear since the connectors and switches at the rear of the instrument might be damaged.

Replace this instrument in the original container. Replace all packing pads and fillers in the exact position which they originally occupied. If the original container is no longer available, use a container that is no smaller than 27 inch x 20½ inch x 10½ inch.

It is important that protection be provided for the rear connectors and switches during shipment. A sheet of stiff cardboard should be placed under the instrument and then folded up to meet the top of the rear panel. The instrument should be bagged and surrounded on all surfaces by cushioning and filler materials. A strong, double wall type corrugated box (350 lb/sq. in. minimum bursting test) has been proven to give adequate service. DO NOT USE A SMALLER OR WEAKER CONTAINER THAN THAT RECOMMENDED ABOVE.

2.1.3 Single Channel with 8-3/4 inch Panel Height

Follow the instructions given in paragraph 2.1.1, except that extra precautions must be taken to prevent the front panel extension with its meter from being bent during shipment. The extended meter must be braced between packing material so that the load force will be distributed evenly over the entire front panel of the instrument.

2.1.4 Six Channel Rack with 8-3/4 inch Panel Height

Follow the instructions given in paragraph 2.1.2, except that the container size must be no smaller than 26½ inch x 25 inch x 13½ inch.

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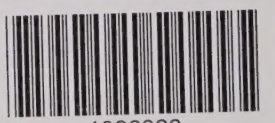

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